



BEAMSTAR FX

Laser Beam Profilers
USER MANUAL

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1 Getting Started

Revision 1.30-1 is the current revision number of this manual. The user should open the PDF edition that is included with the CD-ROM to see if the PDF is a later edition.

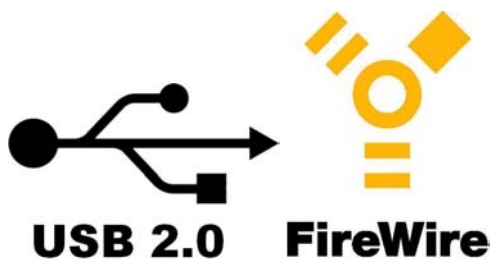
The user should also check Ophir's Web page for the latest updates and FAQs not covered in this manual.

1.1 Manual Overview

This manual describes the following:

- System Requirements and Components
- Camera Connection and Registration
- Installation of the BeamStar Software
- Camera Configuration and Application Setup
- Displays and Analysis

BeamStar supports both USB and Firewire connecting cameras. This manual describes both types, and where discussion refers only to one type, an identifying icon has been inserted in the margin (without its sub-title).



1.2 System Requirements

- Pentium 4, at least 1.7 GHz (>2 GHz for best performance)
- Windows XP Service Pack 2 or Vista 32 bit version

- 256 MB of memory for Win XP, 1 GB for Win Vista
- USB 2.0 for USB cameras

OR

- Firewire IEEE 1394 for FX cameras. Interface cards are normally supplied with FX cameras, requires free PCI or CardBus slot



Note: Camera drivers store settings in the Windows Registry. Therefore, when installing the BeamStar software or when inserting a camera for the first time, the user must be logged in with Administrator Privileges.



Note: If the host computer is using a firewall, see [Firewalls](#), page 20

2 System Components

2.1 Camera Types

BeamStar supports a variety of cameras utilizing USB and Firewire connections. For full details on each of these cameras, refer to [Specifications](#), page 174.



CAUTION: BeamStar cameras are sensitive devices. Please attenuate the intensity of the laser beam on the camera correctly. Failure to do so can cause permanent damage to the camera.

2.1.1 USB cameras



SP503U

- Internal name: SP503U
- ½-in. camera with window size 6.3 x 4.7mm
- External Trigger option for use with pulsed lasers

SP620U

- Internal name: SP620U
- 1/1.8-in. camera with window size 7.0 x 5.3mm.
- External Trigger option for use with pulsed lasers

2.1.2 Firewire FX cameras



BeamStar FX 33

- Internal name: BC101
- 1/3-in. camera with window size 4.7 x 3.5mm
- External Trigger option for use with pulsed lasers

BeamStar FX 33-HD

- Internal name: BC103
- 1/3-in. CCD high resolution camera with window size of 4.8 x 3.6 mm
- External Trigger option for use with pulsed lasers

BeamStar FX 50

- Internal name: BC102
- 1/2-in CCD camera with window size of 6.3 x 4.7mm
- External Trigger option for use with pulsed lasers

2.2 Connecting a camera

2.2.1 USB camera



The cameras are Plug 'n Play and connect directly to a computer's USB port via the supplied cable. This cable is a standard “A to mini B” cable. The Type A connector should be connected to the PC and the mini-B connector to the camera. The operating system should automatically detect the presence of the camera.

2.2.2 Firewire FX cameras



FX cameras connect to the host computer via a Firewire port either on a Firewire card, or directly via an onboard Firewire port on the camera.

When an FX camera is connected for the first time, there is no software driver associated with this camera. Windows will generally ask whether you want it to find and install a driver for the camera. The BeamStar software takes care of the camera driver installation.

The FX cameras can be used with Firewire PCMCIA cardbuses, regardless of whether they have their own power supply. For cards

that do not provide power, Ophir supplies a power adapter for use on laptops. (On desktop PCs there is no need for an external power supply because desktop PCs supply all the power the camera needs.)

You can connect the power using one of the two power connection methods illustrated below.

Built-in power socket

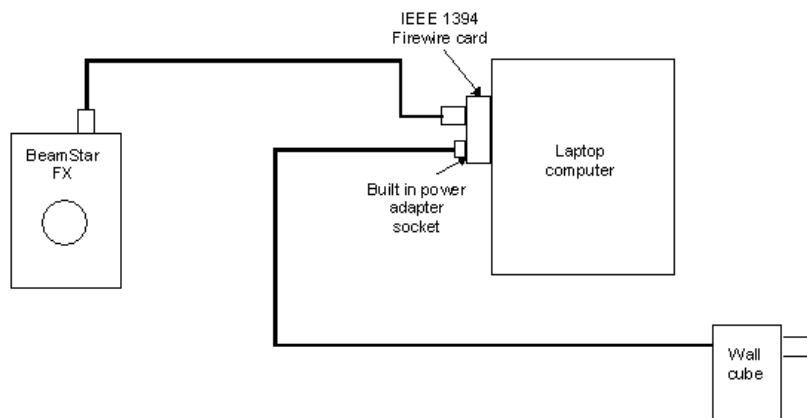


Figure 1: Installation with Firewire card having built-in power socket

No power socket

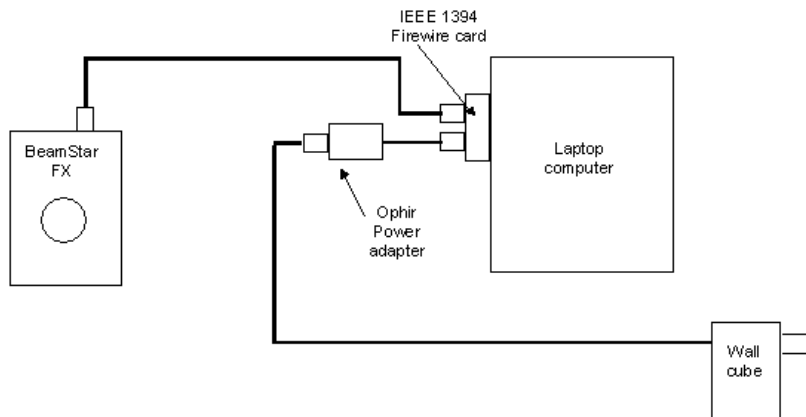


Figure 2: Installation with Firewire card with no built-in power socket



Note: You must have administrative privileges to install the camera.

To connect an FX camera:

1. Set up the PC for Firewire communication.
 - a. For a desktop PC:
 - i. Verify that a Firewire card is mounted in the chassis of the PC or use an onboard port if available.
 - ii. There is no need for an external power supply. Desktop PCs supply all the power the camera needs.
 - b. For a Laptop PC:
 - i. Install the Firewire card in the Cardbus slot of the laptop.
 - ii. If the card has a built-in power adapter socket, plug the wall cube power adapter directly into the Firewire card's power socket.

- iii. If the card does not have a built-in power adapter socket, plug the provided power adapter into the other Firewire card port and connect the wall cube power supply to the power adapter.
2. Verify that the Firewire cable is properly connected at both ends.



CAUTION: Verify that you have plugged the connector in the correct direction. Reverse insertion of a Firewire cable can cause a Firewire device to burn out.

3. Power up the computer.

2.3 Optical Accessories

2.3.1 Filters

In order to operate the camera properly, you must adjust the intensity of the beam so that it is in the range within which the camera is efficient. The usual method is to mount a number of filters. The optimum number of filters is the combination that minimizes attenuation without causing camera saturation.

Three filters are supplied, two in black housings and one in red. The black ones filter more than the red. You can combine the filters to increase attenuation, as shown in the following list:

- Red filter (least attenuation)
- Black Filter
- Red + Black
- Black + Black
- Red + Black + Black (most attenuation)

2.3.2 Other Optical Accessories

Ophir provides additional optical accessories that extend the measurement capabilities of the BeamStar cameras.

- Beam Splitters: To attenuate laser beams that are too powerful for the filters
- UV Converters: To extend the BeamStar's range into the UV
- 4:1 Beam Reducer: To enable measurement of very large spots
- 4:1 Beam Expander: To allow measurement of very small spots

Refer to [Optical Accessories](#), page 164, for a short description of all optical accessories available from Ophir.

3 Software Installation and Camera Registration

After completing the camera connection, as described in [System Components](#), page 12, the BeamStar software (and FX camera drivers) can be installed.

3.1 Software Installation

The installation of the BeamStar software follows a typical Windows installation.

During installation, the program installs a hotfix for Windows XP (if needed) and a driver for the Firewire FX cameras. The hotfix is a Microsoft product, and the driver is digitally signed to be accepted by Windows. Therefore, you may safely respond OK in both cases when asked.

The Windows XP hotfix is needed if not previously installed to ensure correct operation of USB cameras..

Install the software without having a FX camera attached.

Drivers that are needed are loaded automatically from the installation CD.

The installation process checks:

- If Microsoft .Net Framework 1.1 is already installed. If not found, click OK when this step occurs to install it. This will take a few minutes to install.
- If Microsoft WindowsXP-KB899271-v4-x86-ENU Hot-Fix has been installed to update video drivers for USB connections. If not found, click OK when this step occurs to install it.

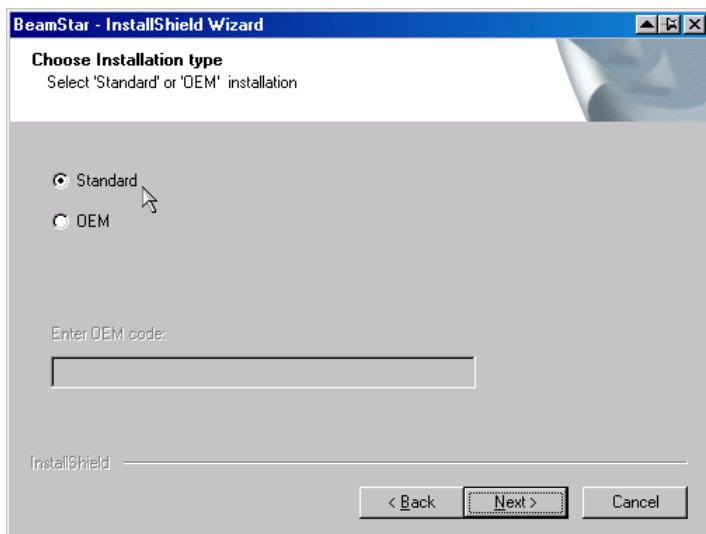
For normal operations, if you start BeamStar without a camera connected, you must register the camera ([Camera Registration](#), page 21).



Note: You must have administrative privileges to install the software.

To install the BeamStar software:

1. Insert the BeamStar FX distribution CD-ROM in the CD-ROM drive.
2. If the CD does not play automatically, then locate and double-click the `index.htm` file.
3. When the selection screen opens, click on the **Install BeamStar** link.
4. When the Choose Installation Type window appears, select **Standard** unless you have purchased an **OEM** package.



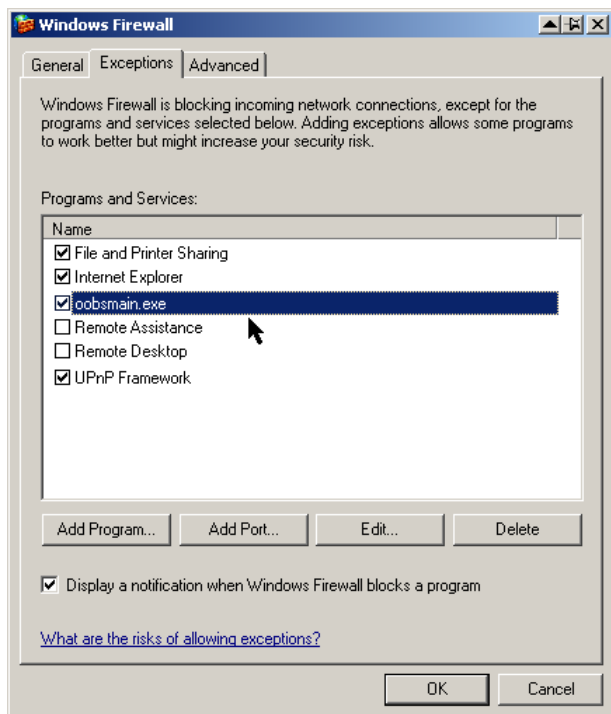
From version 1.02 and higher, Ophir supports customer tailored OEM features in addition to Standard application features. If OEM is selected, the user will be asked to enter the OEM code.

The OEM code is specific to each type of tailored interface ordered. If the code is entered, a special installation (with the requested features) will be performed. For all other customers, the Standard installation is the correct choice.

5. If a Windows dialog box appears stating that it found new hardware, click **Cancel**.
6. Respond appropriately to the dialogs boxes that appear regarding program location, etc. When the software installation finishes, it places on the desktop a shortcut icon that is used to start BeamStar.

3.1.1 Firewalls

Microsoft Windows puts up a Firewall as a security measure to protect the user's PC. The BeamStar installation process sets the BeamStar application (oobsmain.exe) as an exception to the Firewall, allowing it to act as an Automation Server (see [Automation](#), page 163), thereby allowing traffic on port 15113 and enabling Client applications to access the BeamStar. If you get a warning message from the firewall when running BeamStar, then click on the **unlock** button to avoid getting this message again.



If you are using a third party firewall, such as Zone Alarm, then you will have to manually allow the network connection if you are using the BeamStar Automation interface.

In some cases, you may have to manually allow port 15113.

3.2

Camera Registration for FX cameras



Sometimes, the application still does not find the camera after the installation steps, and the following message is displayed when running the BeamStar FX:



This message will also occur if you want to run a new camera that was not yet used with the application.

To refresh the FX camera connection:

1. First, attach the FX camera via the 1394 port, and if using a laptop, make sure its external power supply is connected correctly ([Firewire FX cameras](#), page 13).
2. From the main menu pick **Tools > Refresh Camera Drivers**.

After the installation is completed, you need to configure the software for the type of laser to be measured. BeamStar can be configured to work with continuous or pulsed lasers. This configuration is done within the BeamStar program, see [Camera Configuration Controls](#), page 23. The following sections explain that part of the software. Following the sections on camera configuration, the manual describes BeamStar's measurement and analysis features.

4 Camera Configuration Controls

Controls for the camera are located on three tabbed pages of the Control Panel, see [Figure 3](#), page 23, [Figure 6](#), page 29, and [Figure 10](#), page 44.

See [Setup for Measurements](#), page 32 for a detailed explanation on how to configure the BeamStar for measurement based on these Camera Configuration Controls

4.1 Camera Format Page

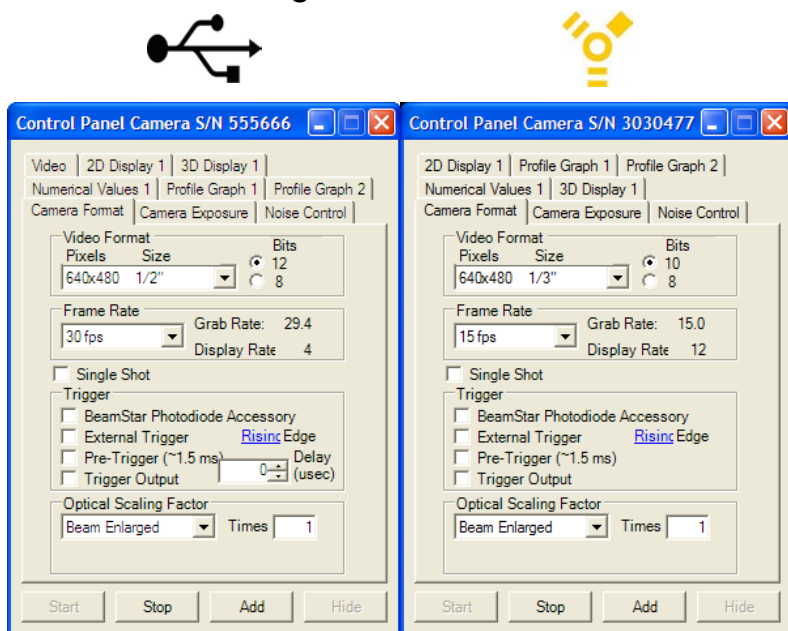


Figure 3: Camera Format Page for USB (left) and FX cameras

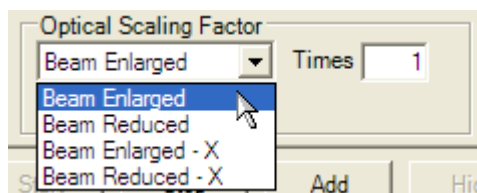
4.1.1 Optical Scale Factor

The Optical Scale Factor offers adjustment of the displayed numerical results for an active camera when using beam reducers or

expanders. This adjustment can be set either collectively or individually for X and Y.

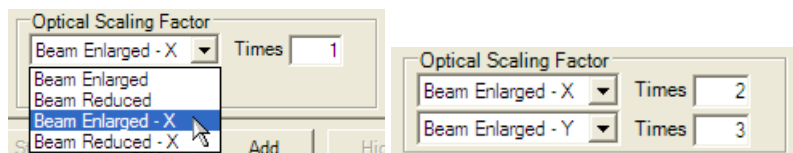
For a list of optical accessories that reduce or expand the beam spot, see [Optical Accessories](#), page 16.

Collectively:



- When working with the 4x Beam Expander, set the Optical Scaling Factor to Beam Enlarged and set Times to 4.
- When working with the 4x Beam Reducer, set the Optical Scaling Factor to Beam Reduced and set Times to 4.

Individually:



- To expand/reduced X and Y individually, set the Optical Scaling Factor to Beam Enlarge -X/Beam Reduced-X. The Times fields will open for X and Y. Set Times to the values required for X and Y.

4.1.2 Video Format

The video formats for the BeamStar cameras are also described in [Camera Types](#), page 12.

The video format is managed from the **Camera Format** page.

- The SP620U has a fixed video format of 1/1.8" 1600x1200 pixels.

- The SP503U and FX 50 have a fixed video format of 1/2" 640x480 pixels.
- The FX 33 has a fixed video format of 1/3-in., 640x480 pixels.
- The FX33HD has a fixed video format of 1/3-in., 1024x768 pixels

4.1.3 Bits

Two bit settings are available:

- USB modes are 12-bit or 8-bit
- FX modes are 10-bit or 8-bit

12-bit and 10-bit modes provide higher numeric resolution and are therefore the preferred settings. However, if the computer is low on CPU resources or if time is a factor, select 8-bit mode.

4.1.4 Frame Rate

The Frame Rate sets the camera's rate of measurement.



Note: Although the PC gathers frames of data at this rate (or close to it), as displayed in the **Grab Rate**, the BeamStar may update its display at a slower rate, as displayed in the **Display Rate**, depending on the set of display windows that are open at the time.

4.2 Trigger Modes

The BeamStar camera supports an extensive set of external trigger options, thereby enabling synching measurements with a pulsed laser.



Note: Trigger options are available with both our USB and Firewire line of cameras.

4.2.1 Trigger Edge option

The Edge option has two settings: Rising and Falling. Clicking on the blue underline settings toggles between these two settings (Rising/Falling). This setting sets both External and Output triggering to the same mode.

4.2.2 Internal

No trigger mode selected. Measurements will be made based on the selected frame rate of the BeamStar camera.

4.2.3 External Trigger

The external trigger mode uses a BNC cable between the laser and the camera. Lasers up to 1 KHz can be synched with this method. The BNC trigger input on the camera can accept either positive or negative inputs.

4.2.4 Ophir Photodiode Trigger (OPT)

The Ophir Photodiode Trigger (OPT) for the USB and FX series simplifies the measurement of pulsed lasers. The photodiode triggers the camera by synchronizing on the light from the laser itself, or from the flash lamp pumping the laser. Therefore, you do not need any physical connection to the laser. The OPT can use lasers of up to 500 Hz.

Characteristics of the photodiode trigger

The Photodiode Trigger responds to wavelengths of 190 nm to 1100 nm. The input to the unit is very sensitive and allows triggering when the peak power exceeds a threshold. It easily triggers on the scattered light from short duration lasers.

When necessary (for example, when working with Optical Accessories or when measuring very weak lasers), the OPT can be separated from the camera and mounted on the optional stand and placed closer to the laser light ([Figure 4](#), page 27)



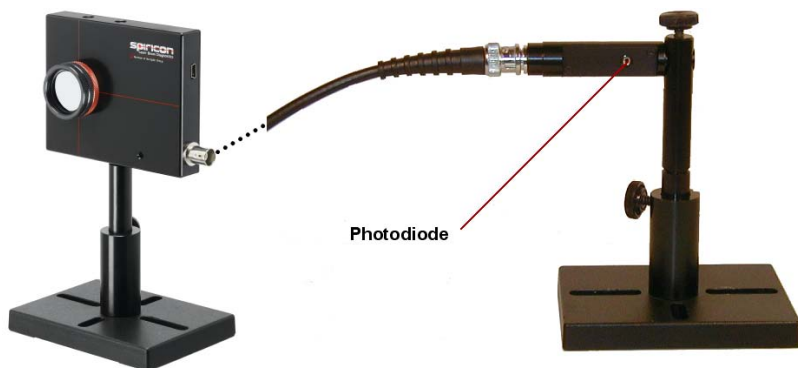


Figure 4: Photodiode trigger with the SP03U camera



For some FX cameras and laser combinations, the OPT can be mounted on the FX camera and connected to the BeamStar with the provided BNC cable, [Figure 5](#), page 27. The photodiode assembly can be swiveled for optimum reception of the trigger light.

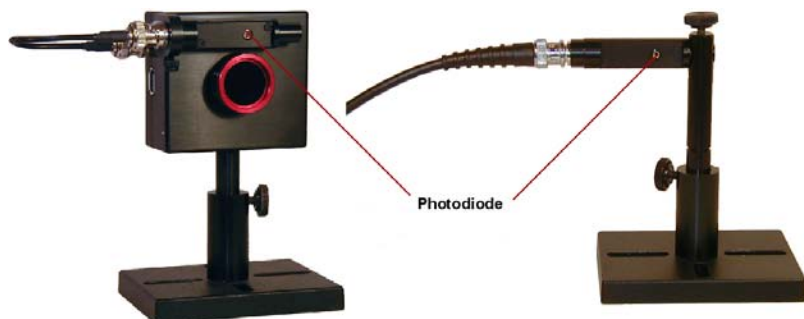


Figure 5: Photodiode trigger mounted on a FX camera and as stand-alone

4.2.5 Pre-triggering

The pre-trigger option is for short laser pulses.

BeamStar FX cameras have an exclusive feature of pre-triggering that can capture pulses no matter how short they are. The Pre-Trigger feature works by timing the trigger signals (either from the laser electrical trigger-out or from the photo-trigger signal). For example, if the laser pulse rate is approximately constant, the circuit can predict after two pulses when the next pulse will arrive. It therefore can arrange to open the laser shutter before the pulse arrives.

Since it takes $\sim 10 \mu\text{s}$ for the BeamStar FX shutter to open after the trigger signal, it is recommended to use the Pre-Trigger option when working with short pulsed lasers.

Some laser outputs already pre-trigger and put out the trigger pulse before the laser pulse. This should be taken into account when setting to pre-trigger or not. If the laser output already pre-triggers, you do not have to set the BeamStar to pre-trigger. Since it takes some $10 \mu\text{s}$ between the trigger pulse and the opening of the shutter, the pre-trigger pulse should be sent at least $15 \mu\text{s}$ before the pulse.

4.2.6 Trigger output

A camera can be set to trigger the laser to fire a pulse. The Trigger Output rate is set by the Frame Rate of the camera.



USB cameras can be programmed to delay the Trigger Output. To do so use the up/down arrows or enter a value (up to 32000 microseconds) in the edit box. This option is only enabled when the **Trigger Output** option is selected.

A screenshot of a software window titled "Trigger". It contains four checkboxes: "BeamStar Photodiode Accessory", "External Trigger", "Pre-Trigger (~1.5 ms)", and "Trigger Output". The "Trigger Output" checkbox is checked. To the right of the "Pre-Trigger" checkbox is a blue link labeled "Rising Edge". To the right of the "Trigger Output" checkbox is a numeric input field containing "6453" and a "Delay (usec)" label.

4.3 Camera Exposure

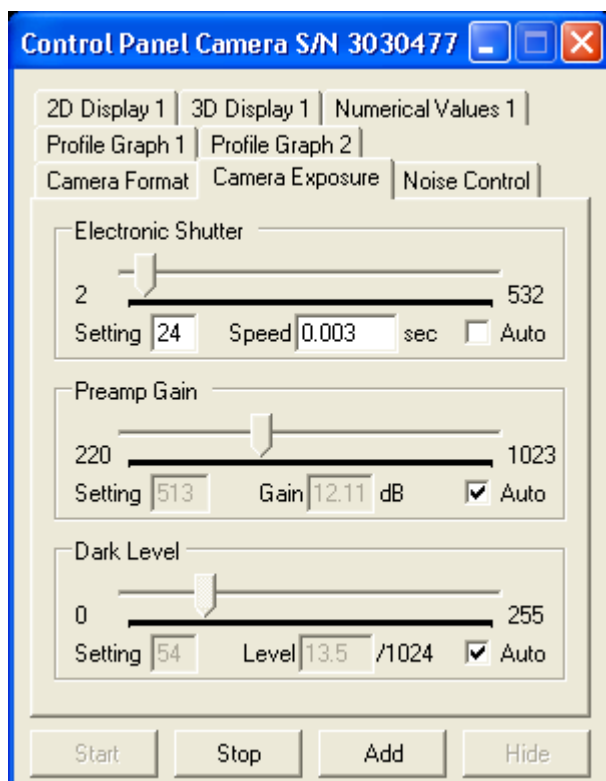


Figure 6: Camera Exposure page

4.3.1 Electronic Shutter

The **Electronic Shutter** setting determines how long the camera shutter remains opened. A longer time setting allows in more laser light to enter.

4.3.2 Preamp Gain

The **Preamp Gain** setting electronically increases the intensity of the signal.

In addition to increasing the intensity of the signal from the laser, a higher gain also increases the intensity of electronic noise. Therefore, the preferred method of increasing signal intensity is to increase the shutter time and to remove filters, if possible.

4.3.3 Dark Level

Dark Level is the numerical level of the pixel raw data that represents absolute dark.

BeamStar allows this value to be above zero, thereby enabling noise to be equally distributed above and below the **Dark Level**.

4.4 Noise Control

The **Noise Control** page lets the user process the laser signal to improve the quality of the measurements.

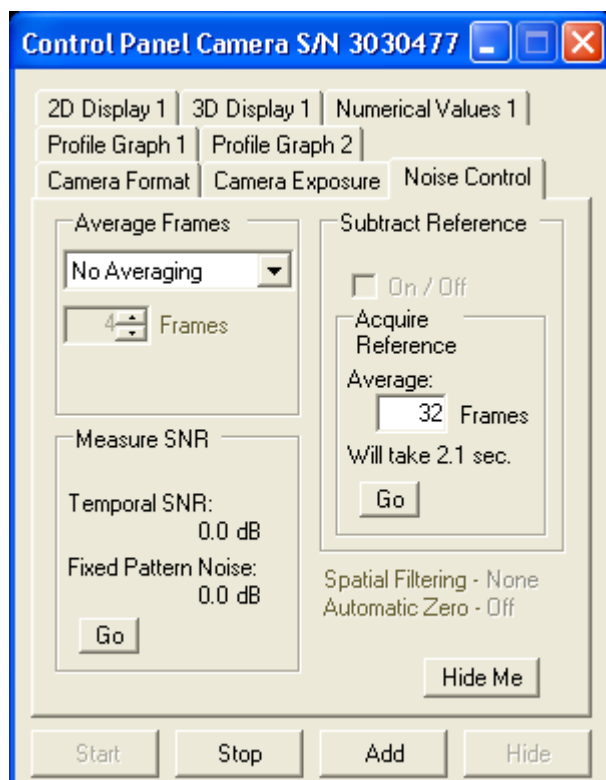


Figure 7: Noise Control page

- **Average Frames:** Reduces noise by averaging multiple frames of data.
- **Subtract Reference:** Allows analysis of the difference between the laser under test and a reference measurement.
- **Measure SNR:** Measures the Signal to Noise Ratio (SNR) of the camera. This is a measure of the quality of the signal processing that the camera is performing on the laser beam.

For detailed explanations, see [Improving the Signal](#), page 43.

5 Setup for Measurements

5.1 Trigger Mode Selection Guide

The following are guidelines for selecting the correct trigger mode for your laser.

- If your laser is continuous or pulses at a frequency greater than 1000 Hz, work in Internal Trigger mode (leave all Trigger options cleared).
- If your laser frequency is up to 1000 Hz, it is recommended to work in External Trigger mode with a BNC cable physically connected to the camera.
- If your laser frequency is up to 500 Hz and you do not want a physical connection between the system under test and the BeamStar camera, use the Ophir Photodiode Trigger (OPT).
- In all cases of External Triggering, if the pulses are less than about 20 microseconds, use the pre-trigger option in addition to the selected Trigger Mode option.

The following sections describe in detail the step-by-step process of setting up the BeamStar camera and application for the laser under test.

5.2 Internal Trigger (CW Mode)

If the measurement is using a free-running camera without external triggering to capture a pulsed laser, the main factor affecting the stability of the measurement is the number of pulses captured per exposed frame. That value will determine the overall exposure stability.

For example:

- Camera Shutter set to 33 milliseconds and Laser Rep Rate to 300 Hz. Number of pulses per frame = 10 ± 1 . Exposure Instability = $\pm 10\%$.

- Camera Shutter set to 33 milliseconds and Laser Rep Rate to 3000 Hz. Number of pulses per frame = 100 ± 1 . Exposure Instability = $\pm 1\%$.

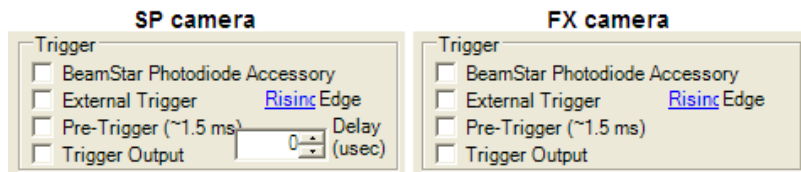
To improve overall exposure stability, set the Shutter Opening to the largest possible setting without saturating the camera.

5.2.1 Optical Accessories setup

1. If required, screw one or more of the supplied attenuating filters onto the camera, see [Filters](#), page 16
2. If required, and you have the optional Beam Splitter, set up the device with the camera.
3. If measuring in the UV range and you have the optional UV converter, set up the device with the camera.
4. If using either the beam reducer or expander, set up the device with the camera and enter the appropriate configuration in the [Optical Scale Factor](#), page 23 on the [Camera Format Page](#), page 23.
5. Start the laser.

5.2.2 Camera Format

1. Select either 12 bits or 8 bits for USB cameras or 10 bits or 8 bits for FX cameras.
2. For pulsed lasers, select a **Frame Rate** high enough to prevent or minimize “flickering” of the 2D Display.
3. Clear all trigger options (see following figure).



5.2.3 Camera Exposure

As Preamp Gain increases not only the intensity of the signal from the laser, but also the intensity of electronic noise, it is preferable to keep it as low as possible while still getting a high signal at the laser beam's beak.

Therefore the suggested method of raising the level of the signal is as follows.

- Set the Electronic Shutter to be open as long as possible.
- If the Electronic Shutter is at the top of its scale, raise the Preamp Gain.
- If the Gain becomes greater than 50% or so of full scale, remove a filter (if possible).
- If the Gain is close to the minimum and the signal is still saturated, add an additional filter.

In CW mode, BeamStar sets the Electronic Shutter, Preamp Gain, and Dark Level controls to Auto mode. It automatically drives the Electronic Shutter as high as necessary and keeps the Preamp Gain as low as possible to ensure a good signal from the camera.

5.2.4 Saving settings

If you intend to make measurements in the future, similar to the ones you are planning to make now, you can select from two options to have these measurement settings loaded the next time BeamStar starts. Refer to [Customizing the BeamStar Startup](#), page 50.

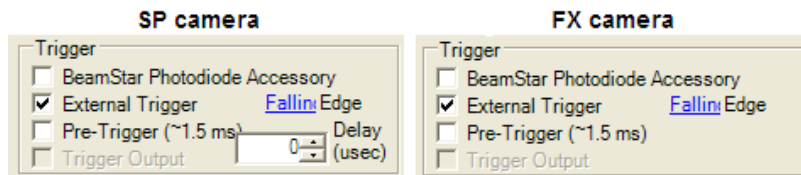
5.3 External Trigger

5.3.1 Optical Accessories setup

1. If required, screw one or more of the supplied attenuating filters onto the camera, [Filters](#), page 16.
2. If required, and you have the optional Beam Splitter, set up the device with the camera.
3. If measuring in the UV range and you have the optional UV converter, set up the device with the camera.
4. If you are using either the beam reducer or expander, set up the device with the camera and enter the appropriate configuration in the [Optical Scale Factor](#), page 23 on the [Camera Format Page](#), page 23.
5. Start the laser.

5.3.2 External Trigger setup

1. Connect a BNC cable between the pulsed laser and the BNC terminal of the BeamStar FX.
2. Select **External Trigger** in the Trigger section of the Camera Format page.
3. Select either the rising or falling edge of the trigger (highlighted in blue to the right of the external trigger checkbox).



You can see if the camera is triggering by looking at the green LED on the rear of the camera.



Note: Verify that the trigger voltage is within the 3 to 24 V range of the camera or the laser controller. The trigger should be about 1 microsecond minimum width.

Note: If your pulses are shorter than $\sim 20 \mu\text{s}$, it is recommended to select Pre-Trigger also (see “Pre-triggering”, page 24).

5.3.3 Camera Format

1. Select either 12 bits or 8 bits for USB cameras or 10 bits or 8 bits for FX cameras.
2. Select a **Frame Rate** high enough to prevent capturing more than one pulse per frame.

5.3.4 Camera Exposure

Electronic Shutter:

- In External Trigger mode, BeamStar puts the Electronic Shutter in manual control and sets it to 3 milliseconds. This is good for most lasers. To prevent BeamStar from changing the Electronic Shutter when selecting Trigger Mode, see [Trigger Mode Behavior](#), page 37.
- If the laser under test has longer pulses, increase the shutter time to slightly longer than the pulse width.
- If the laser is pulsing rapidly you may have to decrease the shutter time (or alternatively, raise the **Frame Rate** of the camera).

- If the pulse is very short and the signal noisy, you may have to decrease the shutter time.

Preamp Gain:

- BeamStar sets the Preamp Gain to Automatic mode. As the Electronic Shutter is adjusted manually, the Preamp Gain may fluctuate or become very high.
- If the picture fluctuates, try turning off the Automatic mode and setting the Gain manually.
- If the Gain level is close to maximum, reduce the number of filters on the camera.
- If the picture is saturated, increase the number of filters.

5.3.5 Trigger Mode Behavior

This behavior option tells the **Electronic Shutter** how to behave when entering the **External Trigger** mode.

You can set a startup option for the Trigger Mode by going to **Tools > Options** from the Menu bar to open the **General** options tab page, see [Figure 8](#), page 38.

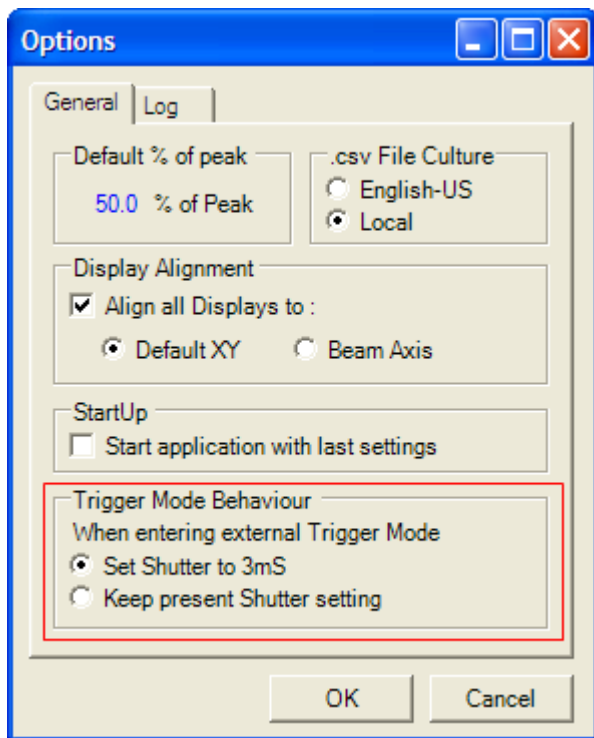


Figure 8: Setting a startup option for Trigger Mode Behaviour

Each example below started with the **Camera Exposure** set to **Auto**.

- **Set Shutter to 3ms** — After entering **Camera Format** and selecting **External Trigger**, the **Auto** option of **Electronic Shutter** is cleared and the slider moves to a speed of 3ms.
- **Keep present Shutter setting** — After entering **Camera Format** and selecting **External Trigger**, the **Auto** option of **Electronic Shutter** remains at the **Auto** setting. If desired, you can clear **Auto** and move the slide to another value. After selecting **External Trigger**, the slide position (speed) is maintained.

5.3.6 Saving settings

If you intend to make measurements in the future, similar to the ones you are planning to make now, you can select from two options to have these measurement settings loaded the next time BeamStar starts. Refer to [Customizing the BeamStar Startup](#), page 50.

5.4 Ophir Photodiode Trigger

For an additional description of the Ophir Photodiode Trigger, refer to [Ophir Photodiode Trigger \(OPT\)](#), page 26.

5.4.1 Optical Accessories setup

1. If required, screw the supplied attenuating filters onto the camera (see [Filters](#), page 16).
2. If required, and you have the optional Beam Splitter, set up the device with the camera.
3. If measuring in the UV range and you have the optional UV converter, set up the device with the camera.
4. If using either the beam reducer or expander, set up the device with the camera and enter the appropriate configuration in the [Optical Scale Factor](#), page 23 on the [Camera Format Page](#), page 23.
5. Start the laser.

5.4.2 Photodiode Trigger setup

1. Mount the photodiode assembly on the camera, and connect it to the camera with the provided short BNC cable ([Figure 4](#), page 27).
2. Swivel the photodiode assembly to the optimum location so that the camera triggers reliably.

You can see if the camera is triggering by looking at the green LED on the rear of the camera.

3. If the camera does not trigger with the photodiode mounted on the camera, mount it closer to the scattered or reflected laser light.

You may use the optional stand and a longer BNC-to-BNC cable if desired.

4. Click the **Camera Format** tab.
5. Select **BeamStar Photodiode Accessory and External Trigger**.

SP camera	FX camera
Trigger ☒ BeamStar Photodiode Accessory ☒ External Trigger Falling Edge ☐ Pre-Trigger (~1.5 ms) ☐ Trigger Output	Trigger ☒ BeamStar Photodiode Accessory ☒ External Trigger Falling Edge ☐ Pre-Trigger (~1.5 ms) ☐ Trigger Output



Note: If your pulses are shorter than $\sim 20 \mu\text{s}$, then it is recommended to select Pre-Trigger also (see “Pre-triggering”, page 24).

5.4.3 Camera Format

1. Select either 12 or 8 bits for USB cameras or 10 or 8 bits for FX cameras.
2. Select a **Frame Rate** high enough to prevent capturing more than one pulse in a frame.

5.4.4 Camera Exposure

Electronic Shutter:

- In External Trigger mode, BeamStar puts the Electronic Shutter in manual control and sets it to 3 milliseconds. This is good for most lasers. To prevent BeamStar from changing the Electronic Shutter when selecting Trigger Mode, see [Trigger Mode Behavior](#), page 41.

- If the laser under test has longer pulses, increase the shutter time to be slightly longer than the pulse width.
- If the laser is pulsing rapidly, you may have to decrease the shutter time (or alternatively, raise the **Frame Rate** of the camera).
- If the pulse is very short and the signal noisy, you may have to decrease the shutter time.

Preamp Gain:

- BeamStar sets the Preamp Gain to Automatic mode. Since the Electronic Shutter is adjusted manually, the Preamp Gain may fluctuate or become very high.
- If the picture fluctuates, try turning off Automatic mode and setting the Gain manually.
- If the Gain level is close to maximum, reduce the number of filters on the camera.
- If the picture is saturated, increase the number of filters.

5.4.5 Trigger Mode Behavior

This behavior option tells the **Electronic Shutter** how to behave when entering the **External Trigger** mode.

You can set a startup option for the Trigger Mode by going to **Tools > Options** from the Menu bar to open the **General** options tab page, see [Figure 9](#), page 42.

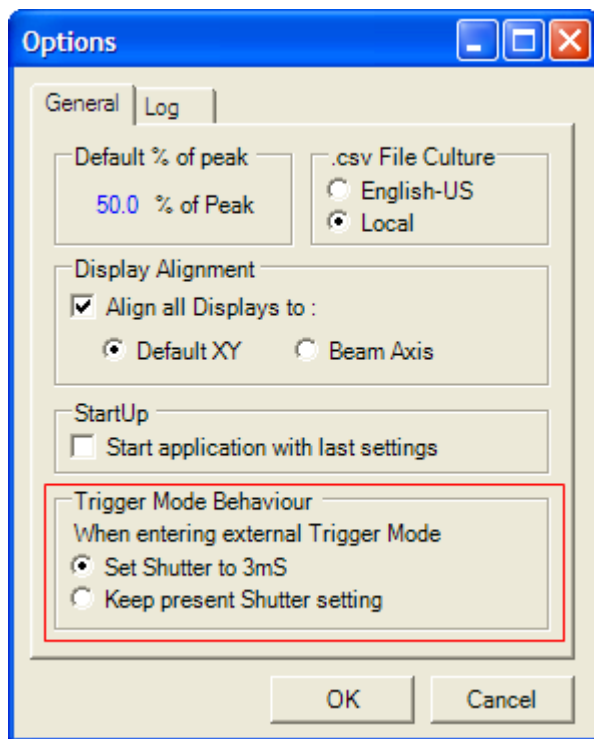


Figure 9: Setting a startup option for Trigger Mode Behaviour

Each example below started with the **Camera Exposure** set to **Auto**.

- **Set Shutter to 3ms** — After entering **Camera Format** and selecting **External Trigger**, the **Auto** option of **Electronic Shutter** is cleared and the slider moves to a speed of 3ms.
- **Keep present Shutter setting** — After entering **Camera Format** and selecting **External Trigger**, the **Auto** option of **Electronic Shutter** remains at the **Auto** setting. If desired, you can clear **Auto** and move the slide to another value. After selecting **External Trigger**, the slide position (speed) is maintained.

5.4.6 Saving settings

If you intend to make measurements in the future similar to the ones you are planning to make now, you can select from two options to have these measurement settings loaded the next time BeamStar starts. Refer to [Customizing the BeamStar Startup](#), page 50

5.5 Improving the Signal

The BeamStar application provides features for measuring and improving the signal quality of the camera.

5.5.1 Background Subtraction

One type of noise that may affect the accuracy of measurements is background noise. This could be, for example, ambient light in the room in which the laser is being tested. When background noise is present, you can subtract the background noise to improve the accuracy of any camera.

To subtract the background noise:

1. Select the Auto exposure checkboxes to set the Gain and Shutter setting.

If performing exposure manually, utilize the maximum Shutter setting before increasing the Gain so that the spot image is just below saturation, indicating the peak is almost white.

2. After the settings have reached their values, clear the Auto checkboxes to fix the settings at those levels.
3. In the tool bar, click the icon for background subtraction.

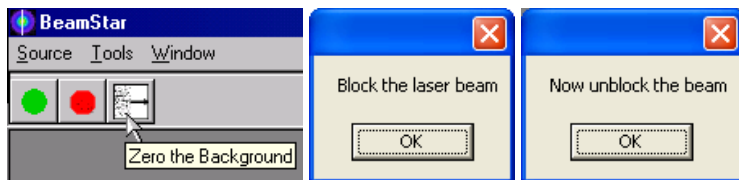


Figure 10: Background subtraction icon and block/unblock messages for external triggering

4. Block the laser when requested by the program.
5. Click **OK**.
6. When background subtraction is completed, unblock the laser as instructed and click **OK**.



Note: This procedure is effective for a particular set exposure level. Any changes in the exposure settings require a re-run of the Background Subtraction procedure.



Note: In general, use the icon on the toolbar to perform background subtraction, and not the Subtract Reference feature.

5.5.2 Frame Averaging

Another cause of inaccuracy is electronic noise. The camera itself may generate noise (especially at very high gains). Pixels are digital in nature, and therefore introduce quantization noise. You can eliminate some of this random noise by averaging.

To eliminate random noise by averaging:

1. In the **Control Panel** page, click the **Noise Control** tab.
2. In **Average Frames**, do the following:
 - a. Select **Averaging**.
 - b. Select the number of frames to average over.

BeamStar will present all data on the screen only after averaging over the number of frames selected.

To cancel this function, set **Average Frames** to **No Averaging**.

5.5.3 Subtracting a Reference

The BeamStar FX can monitor the difference between the beam measured and a reference beam, and look at the difference in signal between the beam measured and the reference beam.

To compare the beam measured with a reference beam:

1. In the **Control Panel** page, click the **Noise Control** tab.
2. Set the beam to the source you want to use as a reference.
3. Set the number of frames you want to average over in acquiring the reference.
4. Click **GO**.
5. Click Subtract Reference **On/Off** to **On**.

Subsequent to the above actions, all beam measurements will be presented with the reference beam subtracted from the measurement. You will be able to use this function to see subtle differences or changes in time between the reference measurement and the beam as seen now.

To cancel this function, click **On/Off** to **Off**.

5.5.4 Measuring SNR

BeamStar can measure the performance of the system in terms of signal to noise ratio (SNR). The SNR is divided into two parts:

- The part based on random noise, which is given by Temporal SNR.
- The part based by noise or variations built into the CCD, which is always the same and given by Fixed Pattern Noise.

To determine the SNR:

1. In the **Control Panel** page, click the **Noise Control** tab.
2. Set BeamStar to a non-fluctuating source or to no source at all.
3. Click **GO** on the **Measure SNR** box.

After several seconds, the result will appear.



Note: An SNR of 60dB is equivalent to a dynamic range of 1000:1 or ~10 bits; an SNR of 50dB is equivalent to 316:1 or ~8.3 bits, and so on.

Note: The SNR may not give correct results when the camera is set to 8 bits. The reported SNR may show higher than it actually, due to the fact that there is not enough resolution at the low end to show the true noise level.

6 BeamStar Operation Basics

6.1 Default Startup

With the camera active when you start the BeamStar program, you will see a display similar to that of [Figure 11](#), below. This is the default startup with a working camera, provided you have not already selected any of the startup options described in [Customizing the BeamStar Startup](#), page 50.

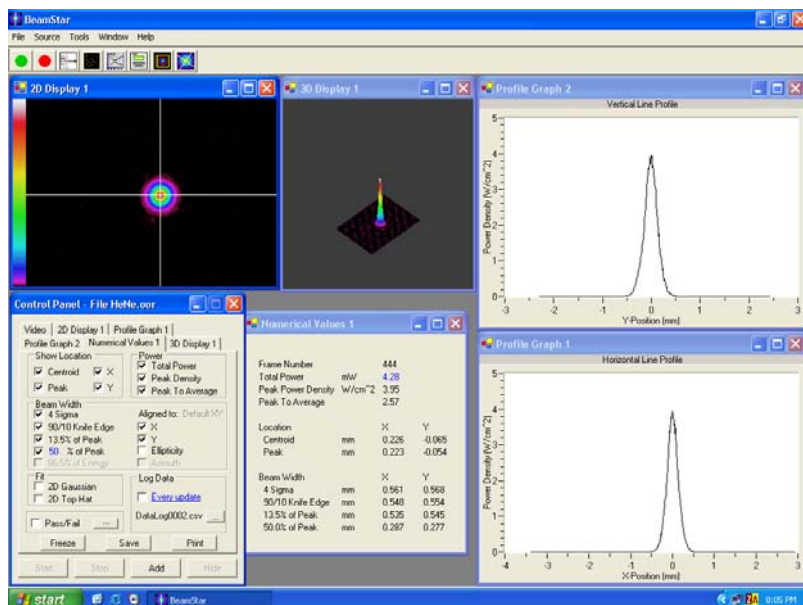


Figure 11: Default start up display

BeamStar can display any combination or number of displays and profiles. Each display is controlled by its own control page. Beginning with the lower left corner display, and moving clockwise, the displays are:

- Control Panel form containing a page for each of the various displays

- 2D Display
- 3D Display
- Profile Graph 1
- Profile Graph 2
- Numerical Values 1



Note: There are other numerical and display functions not shown in [Figure 11](#), page 47. These are described later in this manual.

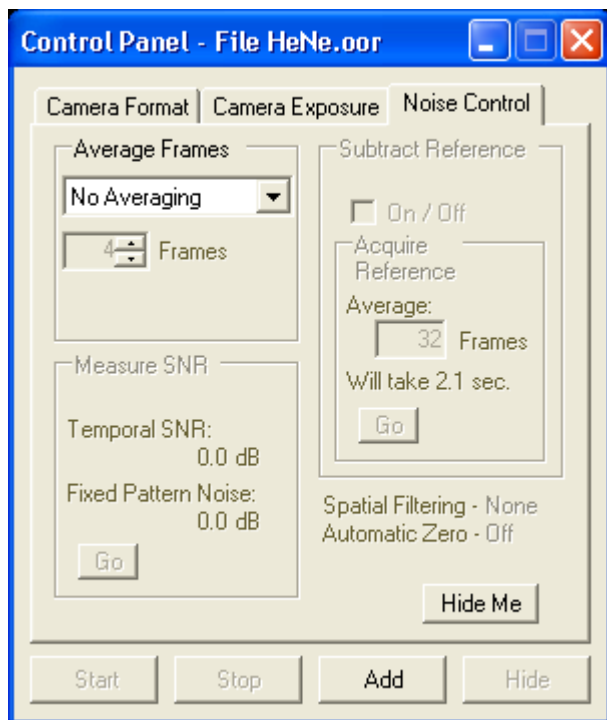
Note: The control pages contain numerous options, some of which are grayed out until the user selects some other option on the page. Other options are permanently grayed out and will be available in a future software release.

6.2 Control Panel

The **Control Panel** holds a page for each display. Each of the pages is brought to the front by clicking its tab. Clicking the Control Box "X" of a display closes the display and its page in the **Control Panel** form. The **Camera** forms cannot be closed. Clicking the Hide Me button closes the **Noise Control** form. Clicking the Control Box "X" of the **Control Panel** form closes all opened displays and pages.



Note: The title bar displays the serial number of the working camera.



The four bottom buttons appear below every page, but are individually enabled depending on the operational activity of BeamStar. Their functions are:

Start Restarts the camera; restarts the video

Stop Stops the camera. If the **Video** add-in is being used, it stops the recording process

Add Opens the **Add** form for selecting additional activity pages (see below).

Hide Not enabled in this software version.

6.3 Add Panel

The **Add** form button is available from any of the pages of the **Control Panel**. Clicking one of the buttons when it is enabled, adds

that activity as another page to the **Control Panel** form. If a display or numerical activity is already present, BeamStar adds a different suffix number to the name of the page; for instance, **Profile Graphs 1** and **2**. Camera functions can have only one instance.

The buttons in the rightmost column represent Camera Control activities where only one instance is allowed. If one of these buttons is enabled the activity can be started.



Figure 12: Add dialog form

6.4 Customizing the BeamStar Startup

If you intend to make measurements in the future, similar to the ones you are planning to make now, you can choose to have these measurement settings loaded the next time BeamStar starts.

- **Startup (Next Session)**

Reloads the last BeamStar settings when you restart BeamStar.

- **Using OOI files option**

BeamStar settings are stored in an OOI file. You can click OOI file in Explorer to start BeamStar with those saved settings.

This option overrides the **Startup** option.

6.4.1 Startup (Next session)

To save the present configuration for the next time, click **Tools > Options**, and then click **Start Application with Last Settings**. If you do not choose this option, BeamStar will revert to the factory defaults every time it is opened.

This options lets you begin the next session of BeamStar with the same displays and features. that were active when you closed the program.

To activate this option

1. Select **Tools > Options** from the menu bar.

The General tab of the Options dialog box.

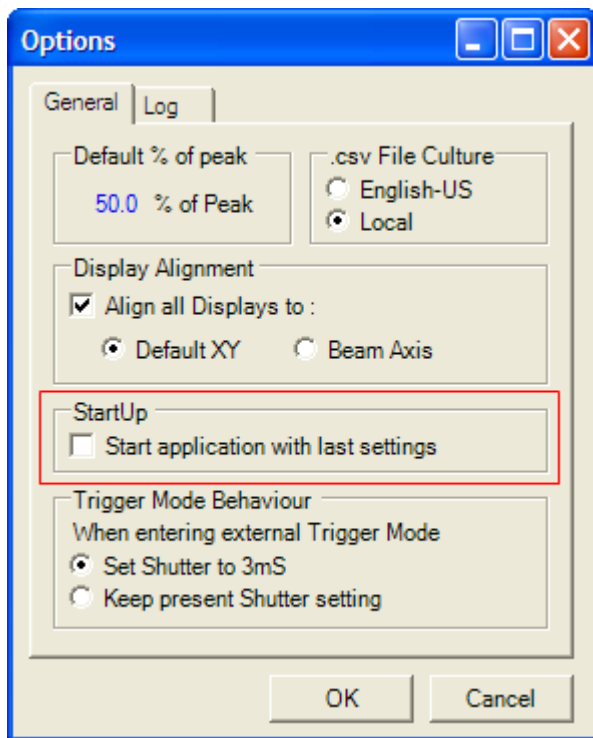


Figure 13: Setting a startup option

2. Select the **StartUp–Start application with last settings** check box.

This option remains active for every BeamStar session until you clear it in this dialog box.

6.4.2 Using OOI files

This option lets you save various working displays BeamStar OOI files. You can activate these OOI files during a BeamStar session, or you can start BeamStar using the saved settings in these files.

The **Next Session Startup** feature is a special case in which BeamStar generates an OOI file automatically.



Note: The criteria selections for the Pass/Fail option that is available in some of the numerical displays is also saved in the OOI files. See [Pass/Fail](#), page 76 for an example.

To save a working session:

1. Verify that you have selected the displays and other features that you need.
2. From the menu bar, select **File > Save settings to...**

A standard **Windows Save As** dialog box opens.

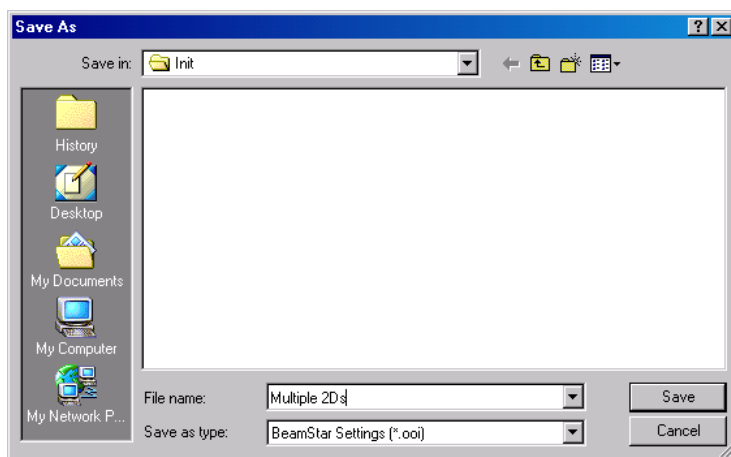


Figure 14: Saving settings to an OOI file

3. Enter a descriptive name for the file and click **Save**.

The file is stored in the Init folder in the path
...\\Ophir Optronics\\BeamStar.

To activate a saved OOI file

1. From the menu bar, select **File > Load settings...**

A standard **Windows Open** dialog box opens.

2. Select the file and click **Open**.

BeamStar reads the file and uses the information to open the desired displays.

Alternatively, when BeamStar is not running:

1. Create a shortcut to the OOI file on the Desktop.
2. Click the shortcut.

BeamStar starts up using the settings in the OOI file for the startup displays.

7 The 2D Display

The 2D Display shows the beam in the x-y plane using the default XY axes mode and Rainbow color mapping (see [Figure 15](#), page 55. Refer to [Table 1](#), page 57 for an explanation of the 2D Display page ([Figure 16](#), page 56).

The 2D Display can also be displayed using the Major/Minor or Beam Axis mode (refer to [Axis Alignment Control](#), page 141).

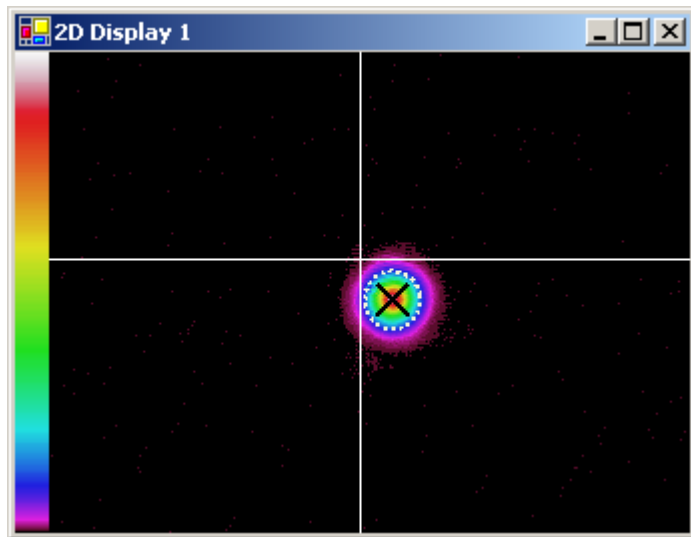


Figure 15: 2D display with Align XY Cursors set to Manual, and the XY Cursors and Centroid (x) Markers selected

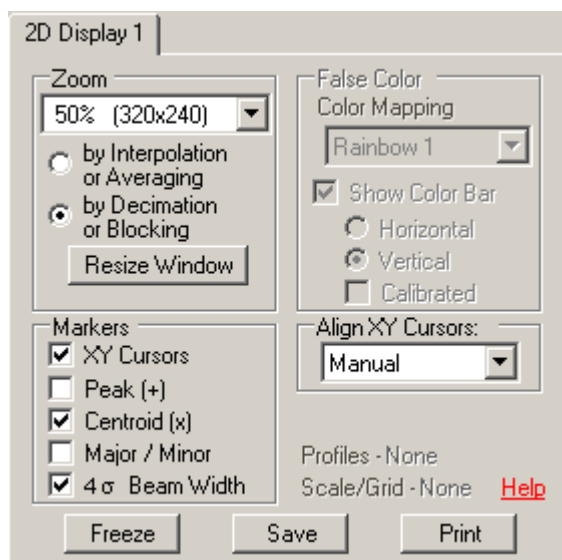


Figure 16: 2D display control when Master Alignment is *not* selected

Table 1: 2D Display control options

Option	Explanation
Zoom	Sets the resolution and size of the picture in the display window (see page 57).
AlignXY Cursors	Sets the position of the two axis-parallel lines in the picture (see page 60). These lines will set the “slice” that is shown in Profile displays (see Profile Graphs , page 81).
Markers	Marks specified features in the picture (see Markers , page 60).
Freeze/UnFreeze	Toggles on/off updating of the 2D display. Cursor movement is still active in Freeze mode. Thus, slices can still be chosen for Profile displays.
Save	Saves the displayed picture in a graphic format or in CSV (comma separated value) file format (see page 65).
Print	Starts the Windows Print Manager to select an output printer. The full frame of the display is printed. The actual data frame depends on when the printing is initiated.
Help	Opens a Help screen describing mouse functionality within the 2D Display.



Note: Once BeamStar has recognized the attached camera, it automatically displays the 2D and 3D displays unless startup options are in use.

7.1 Zoom

The 2D Display can be reduced to as little as 12.5% of the original display (6.25% for FX 33-HD) and can be expanded up to 1600%. To reduce/expand the original display, click the **Zoom** drop-down menu and choose the size desired. You may then resize the window automatically or manually. To resize automatically, click **Resize Window**. To resize manually, drag the corners of the window to the desired size and use the sliders to position the picture where desired.

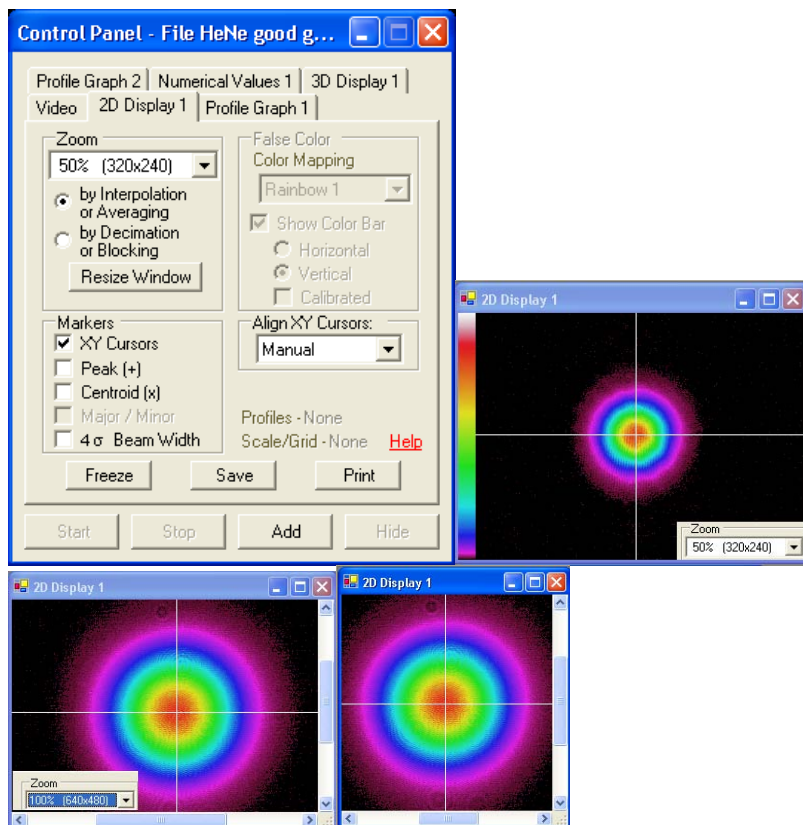


Figure 17: 2D display control and resizing: 1- original 50%, 2-zoom to 100%, 3-resize window



Note: A Zoom factor affects both axes. Thus, a zoom factor of 50% brings about a display of 1/4 the size of the CCD array. A zoom factor of 200% creates a display 4 times the actual size of the CCD array.

BeamStar offers two methods of displaying the data when the Zoom Factor is other than 100%.

- by Interpolation or Averaging (for smoothing “choppy” displays)

When zooming below 100%, the points in the displayed picture will be by **Averaging** together points based on the Z%/100%. For example, zooming to 25% means that a block of 4x4 pixels will be averaged together.

When zooming above 100%, the point value in the displayed picture will be by **Interpolation** between points created by Z%/100%. For example, zooming to 200% means that the process interpolates between two points for each axis.

- by Decimation or Blocking (for quicker display updates)

When zooming below 100%, the points in the displayed picture will be by **Decimation**, meaning that it skips points based on Z%/100%. For example, zooming to 25% means that every fourth point is used on each axis. See also [CSV examples](#), page 66.

When zooming above 100%, the points in the displayed picture will be by **Blocking**, using a point value to build a block based on Z%/100%. For example, zooming to 200% means that each pixel will be expanded into a block of 2x2 pixels.



Note: The Zoom Factor of the 2D Display is visual only and has no effect on other displays and calculations. To use a reduced data set in other displays, use the [Region of Interest](#), page 133.



Note: The 2D Display Window is limited in size to 1600x1200 pixels. If the Zoom Factor selected results in a display greater than 1600x1200, BeamStar will freeze the Display size. The user will be able to navigate through the 2D Display using the scroll bars. The Display Mode will be set to Blocking.

7.2 Cursor Alignment

Cursor location determines the zero coordinates of Profile Graphs (refer to page 81) if **Aligned to Cursors** is selected. The following options exist:

- **Manual**

Each cursor line can be moved in either direction, parallel to its present position.

- **Peak**

The lines are moved to the mathematically determined peak coordinates.

- **Centroid**

The lines are moved to the mathematically determined centroid coordinates.

7.3 Markers

The following Markers options exist (see also [Figure 18](#), page 61 and [Figure 19](#), page 62):

- **XY Cursors**

Enabled when DefaultXY is used. Toggles the cursors on/off in the picture. If *not* selected, **Aligned to Cursors** in the Profile Graph page will align to the last displayed cursor position.

- **Peak (+)**

Places a marker at the mathematically determined peak.

- **Centroid (x)**

Places a marker at the mathematically determined centroid.

- **4 σ Beam Width**

Draws a dotted ellipse using the Centroid as the center and using the 4σ beam widths to define the size of the ellipse.

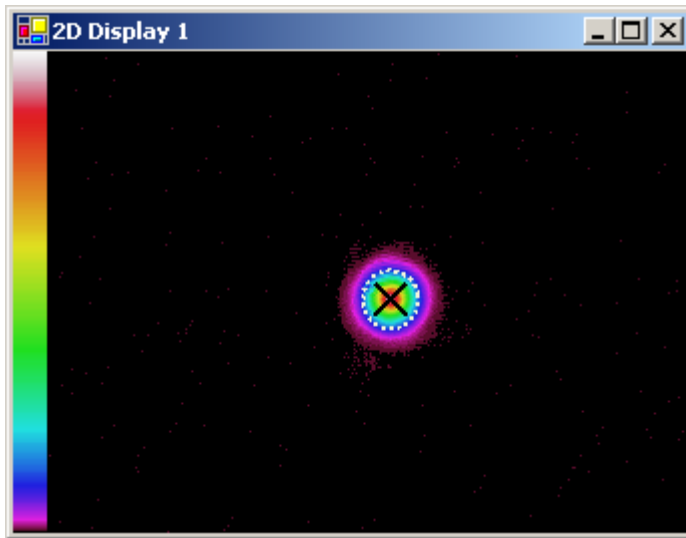


Figure 18: Example of 2D display with Centroid and 4σ beam width Markers selected

- **Major / Minor**

A laser spot might not lie exactly on the XY axes. In such a situation, the XY Markers do not reflect a true cross section of the beam. Also, the 4σ beam width will not encircle the spot correctly.

Select the Major/Minor marker to draw dotted white lines through the true orthogonal cross-sections of the beam. When selected, it also causes the 4σ beam width Marker (if selected) to correctly encircle the beam

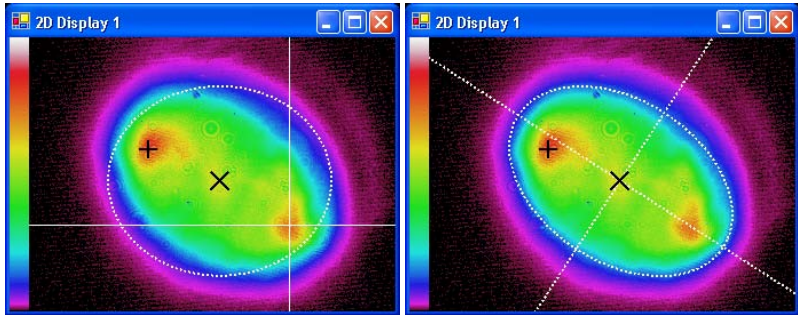


Figure 19: Examples of Axis, Peak(+), Centroid(x), and 4σ markers for DefaultXY (left) and Beam Axis (right)

- **Display Alignment**

Sets globally all of the display axes together to align either the XY axis or the major/minor axis of the beam.

7.4 Distance Measurement

The 2D display features a method to measure linear distances between any two user-selected points and to draw a labeled line between them. Distance results are shown in a separate window.

To measure linear distances:

1. Move to the location in the display where you want the line to start.
2. Right-click the mouse, and move the mouse to the display location where the line will end.

As you drag the mouse, a dashed line is drawn to show you the progress.

3. When you reach the final location, right-click the mouse again.

The dashed line becomes a solid line, and a number appears near the starting location to identify the line.

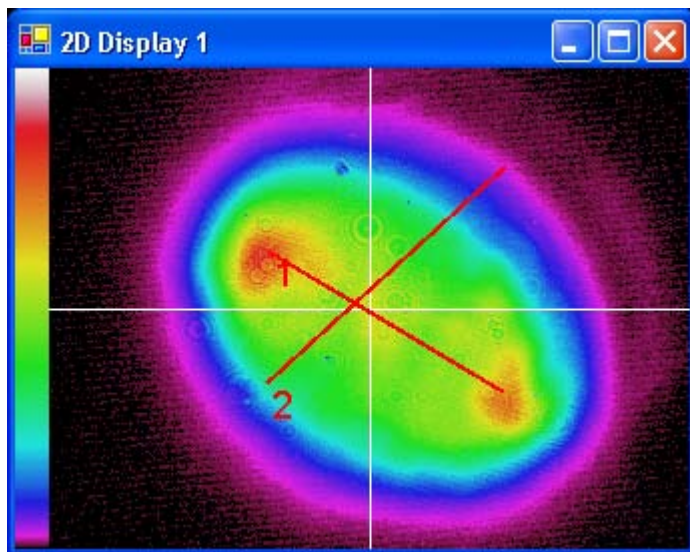


Figure 20: 2D display showing two distance measurement lines

After the first line is drawn, the 2D Display Distance Measurement window opens (see [Figure 21](#), page 64 and [Table 2](#), page 65).

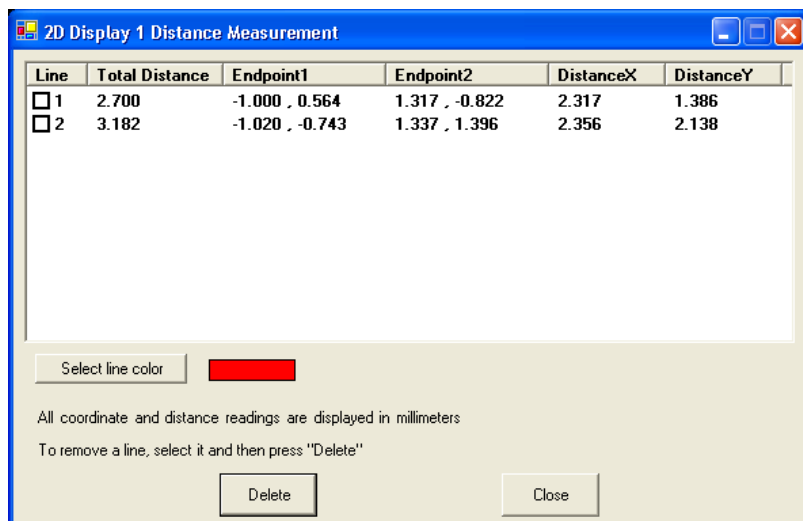
**Figure 21: 2D Distance Measurement window**

Table 2: 2D Display Distance Measurement window

Option	Explanation
Line	The label for the line. If the adjacent check box is selected, the line will be deleted when you click the Delete button.
Total Distance	The length of the straight line from Endpoint1 to Endpoint2. This is calculated according to the formula $\sqrt{(\text{DistanceX}^2 + \text{DistanceY}^2)}$.
Endpoint1	X, Y start location of the line as measured from the camera's center.
Endpoint2	X,Y end location of the line as measured from the camera's center.
DistanceX	The length of straight line along the X Axis between Endpoint1 and Endpoint2.
DistanceY	The length of the straight line along the Y Axis between Endpoint1 and Endpoint2.
Delete	Clicking the button removes the selected line.
Close	Closes the window and removes all lines from the 2D Display.

7.5 Save

Save opens a standard Windows Save As dialog box in which you can choose to save the current 2D Display either as a graphic file or as a CSV file.

To save a 2D display

1. Click the tab for the 2D Display of interest so it has the focus.
2. Click **Save**.
A standard Windows Save As dialog box opens.
3. Navigate to the folder where you want to save the file.

4. In **Save as type**, select the type of file as follows:

- For a graphic file, select a **bmp**, **png**, **gif**, **jpg**, or **tiff** format.

The graphic file saves the complete display, picture, and border in the format you select. The picture in [Figure 18](#), page 61 is an example.

- For a CSV file, select either **Viewed Area** or **Full Frame**.

View Area Saves the points displayed based on the **Zoom** settings.

Full Frame Saves the points in the entire data in the frame.

Region of Interest (ROI) Saves the points in the area bounded by the ROI box (see [Region of Interest](#), page 133).

5. Click **Save** to complete saving the file, or click **Cancel** to abort the operation.

7.5.1 CSV examples

Saving data to a CSV file saves the raw pixel data as measured by the camera. This is useful for users that want to perform independent in-house analyses on the data.

The examples below show a partial view of the CSV files saved for a 2D Display set at 50% using the three available options: View Area, Full Frame, and ROI.



Note: The default language of any CSV file is the same as that of the local computer.

50%ViewArea.csv						
	A	B	C	D	E	F
1	Pixel Width	2 *	0.0074 mm			
2	Pixel Height	2 *	0.0074 mm			
3	Power Density	Multiply by	4.65E-04 W/cm^2			
4	Dark Level	Subtract	360			
5	Power Density	=	(n - 360) * 4.649e-004 W/cm^2			
6		1	3	5	7	9
7	1	368	408	328	368	360
8	3	416	416	360	360	400
50%ViewArea/						
50%ROI.csv						
	A	B	C	D	E	F
1	Pixel Width		0.0074 mm			
2	Pixel Height		0.0074 mm			
3	Power Density	Multiply by	4.65E-04 W/cm^2			
4	Dark Level	Subtract	360			
5	Power Density	=	(n - 360) * 4.649e-004 W/cm^2			
6			252	253	254	255
7	172		928	1088	960	896
8	173		1056	992	1152	1056
50%ROI/						
50%FullFrame.csv						
	A	B	C	D	E	F
1	Pixel Width		0.0074 mm			
2	Pixel Height		0.0074 mm			
3	Power Density	Multiply by	4.65E-04 W/cm^2			
4	Dark Level	Subtract	360			
5	Power Density	=	(n - 360) * 4.649e-004 W/cm^2			
6		0	1	2	3	4
7	0	384	384	480	416	320
8	1	384	320	352	384	352

Figure 22: 50% examples of View Area, ROI, and Full Frame

8 Numerical Values

BeamStar provides comprehensive numerical analysis routines to characterize the beam. Refer to [Table 3](#), page 70 for an explanation.

All numerical analyses use the full data complement of the frame(s) and are not limited to the data being displayed in a 2D or 3D window. To perform calculations on a reduced set of data, use the feature, [Region of Interest](#), page 133.

Readout values can be normalized to follow the actual total power of the laser beam. Refer to [Total Power](#), page 72.

The analysis can be based using DefaultXY or Beam Axis mode (see [Major/Minor Axes](#), page 140). This option only affects the Beam Width values and the 2D Gaussian Fit.



Note: Some options are grayed out because they are for future software versions.

To start a numerical analysis:

1. If the Numerical Values page is not present, click **Add** and then click **Numerical Values** to add the page to the Control Panel form.

Most of the analyses are pre-selected for both the X-axis and Y-axis (DefaultXY) or for Beam Axis modes. The results are reported in the Numerical Values display ([Figure 24](#), page 69).

2. Edit the selections on the page as required.

For both axis alignment modes, selecting any option on or off updates the Numerical Values display. Clearing an option removes it from the Numerical Values display.

The options shown here for Numerical analysis are based on the displays of [Figure 19](#), page 62.

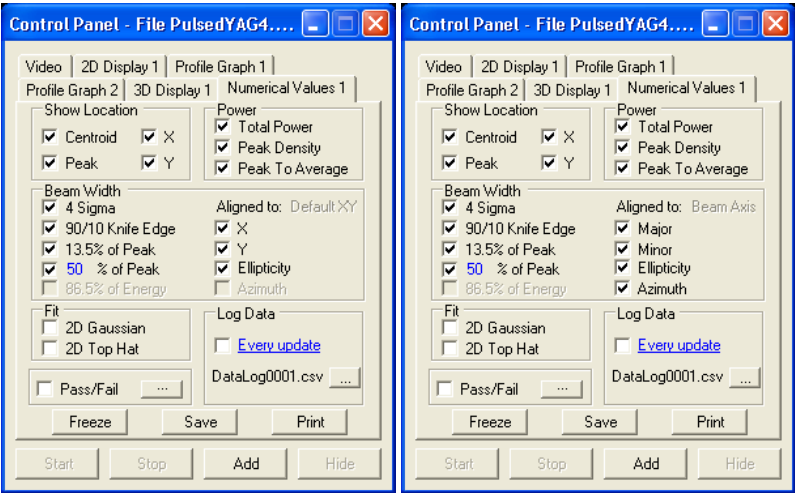


Figure 23: Numeric page, DefaultXY (left) and Major/Minor axis alignments

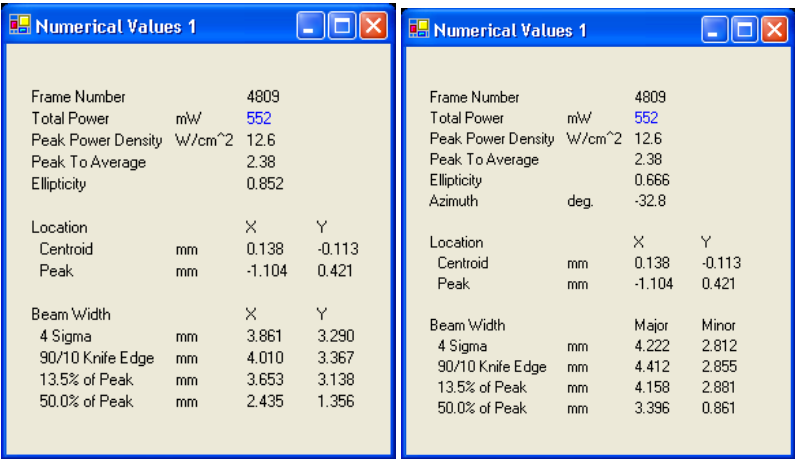


Figure 24: Numeric display, DefaultXY (left) and Major/Minor axis alignments

Table 3: Numerical Values options

Option	Explanation
Show Location	These options are available in both Axis Alignment methods.
Centroid	Displays the coordinates of the calculated “center of mass”. See Beam Width and Centroid , page 146.
Peak	Displays the coordinates of the measured peak.
X	The horizontal location of the Centroid and the Peak.
Y	The vertical location of the Centroid and the Peak.
Beam Width	See Beam Width , page 73.
4 Sigma	Sigma is the second moment value in one dimension. Statistically, this is equivalent to the standard deviation. For instance, the sigma in X is the (intensity weighted) standard deviation of X of the beam. Sigma multiplied by 4 is equivalent to the beam width. See Beam Width and Centroid , page 146.
90/10 Knife Edge	Simulates a knife-edge moving across the beam while the total power is being measured. The position of the knife is taken when the measured power is 90% of the unobstructed beam. Then the position of the knife is taken when the measured power is 10% of the unobstructed beam. The distance between the two knife positions is multiplied by the factor 1.561. This is equivalent to the 90/10 knife-edge measurement of the beam width.
13.5% of Peak	13.5% of the peak is the $1/e^2$ point. For an ideal Gaussian beam, the beam width at the $1/e^2$ point, the 4σ beam width, and the 90/10 knife-edge width, as defined above, will all be the same.
XX % of Peak	This is the width at the point that is the defined percent of the peak power. In Figure 23 , page 69, $XX\%=50.0$.

Option	Explanation
Align to	Select between DefaultXY axes and Major/Minor (Beam Axis) axes.
X (DefaultXY)	When selected, displays the numerical option results in the Numerical Values display for the X-axis. If not selected, the entire X column is removed.
Y (DefaultXY)	When selected, displays the numerical option results in the Numerical Values display for the Y-axis. If not selected, the entire Y column is removed.
Major (Beam Axis)	When selected, displays the numerical option results in the Numerical Values display for the Major-axis. If not selected, the entire Major column is removed.
Minor (Beam Axis)	When selected, displays the numerical option results in the Numerical Values display for the Minor-axis. If not selected, the entire Minor column is removed.
Ellipticity (DefaultXY and Beam Axis)	Displays the ellipticity of the laser spot as Smaller Beam Width / Larger Beam Width. A perfectly circular beam has an ellipticity of 1.00.
Azimuth (Beam Axis)	Displays, in degrees, the angle of rotation between the laser beam's Major Axis and the camera's X-Axis.
Power	
Total Power	Total power in mW, shown in blue in Numerical Values display. This value can be normalized for known laser beam powers (refer to Total Power , page 72)
Peak Density	Peak density, in watts/cm ² .
Peak to Average	Result of Peak Height divided by Average, where Average is the average of all the points that are at least $1/e^2$ (~13.5%) of the peak. A perfect flat-top beam has a Peak to Average ratio of 1.
Fit	
2D Top Hat	See 2D Top Hat , page 75.

Option	Explanation
2D Gaussian	See 2D Gaussian , page 75.
Pass/Fail	Option to set criteria for pass/fail results, based on values set in the Numeric Pass/Fail Setup dialog box. To set up Pass/Fail criteria, click the adjacent browse button. Refer to Pass/Fail , page 76.
Log Data	See Log Data , page 78.
Every update	(Default) Stores the values displayed in the Numerical Values page at a pre-selected interval. The data is CSV (comma-separated) formatted, so it is easily read into Excel or a text program.
DataLog*.CSV	Shows the file name of the next log file to be created. Use the adjacent browse button to change the name and/or its storage location. If you want to use your own names, you must define it before the next logging. Otherwise, BeamStar updates its default name with the next number.
Control Panel	
Freeze	Toggles on/off updating of the Numerical Values display.
Save	Saves the Numerical Values display as a graph in user selected format of bmp, png, gif, jpg, or tiff.
Print	Starts the Windows Print Manager to select an output printer. The full frame of the display is printed. The actual data frame depends on when the printing is initiated.
Help	Opens a Help screen describing mouse functionality within the 2D Display.

8.1 Total Power

By default, the value reported as **Total Power** is relative. That is, the value is the sum of all charges from the pixels of the CCD of the camera. However, if you have the actual power of a laser beam from an independent measurement, you can normalize the **Total**

Power value. Doing so will also normalize all other readouts related to power in all the displays.



Note: This option is available only when BeamStar is displaying camera output and not a video recording file.

To set the laser power

1. Click the **Numerical Values** tab.
2. In the total power line, click the blue value.
3. Type the laser power.
4. To activate the choice, click in another panel.

From this point on, the y-axis of the profiles and numerical readouts shows the correct values of profile power density in watts/cm^2 .

8.2 Beam Width

The BeamStar FX, due to its sophisticated background subtraction and calculation algorithms, gives very accurate measurements of beam widths. To further improve the accuracy, frequently block the laser beam and perform a background subtraction.

BeamStar FX offers four methods of calculating the beam width (see [Table 3](#), page 70). The methods for the calculations are defined so that the results for Beam widths are independent of cursor locations, line profiles, or sum profiles. They are, however, dependent on the Axis Alignment mode (see [Figure 24](#), page 69).

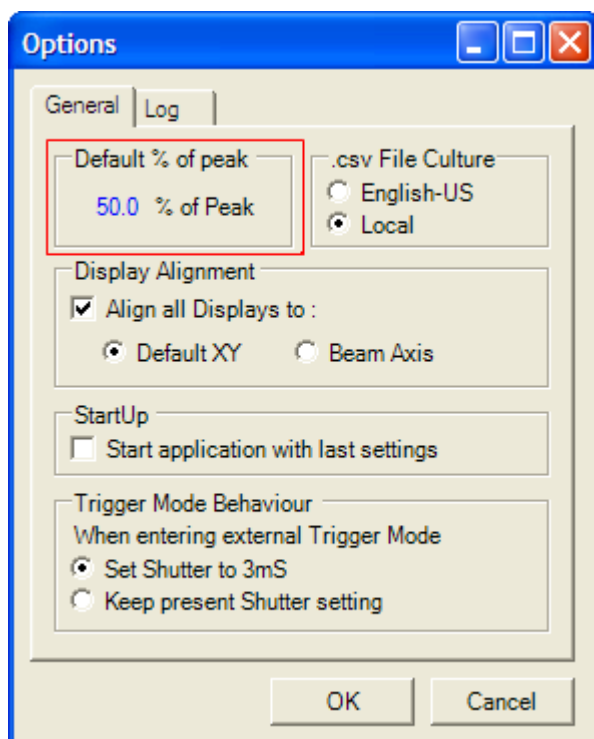
For a Gaussian beam, the three methods – **4 sigma**, **90/10**, and **13.5% of peak** should be equivalent. As you can see in the example, their values are very close.

The fourth method, **XX% of peak**, offers a user-defined setting of the interested percent of peak of the Gaussian curve for the analysis. If you click the blue value in the Numerical Values page (see [Figure 23](#), page 69), the default **50.0%** can be changed to any percent of peak. After choosing the new value, click **Enter** or

toggle any option's state on the page, and the value will be activated.

Default % peak

When customizing the startup options (see also [Customizing the BeamStar Startup](#), page 50) there is an option that lets the user set the value of the **Default % peak** when a stored *.00r is opened. This value overrides what is presently set on the **Numerical Values** panel. Afterwards, if desired, the user can go to the **Numerical Values** panel and select another value for the desired % peak.



When saving an *.00r file, BeamStar only stores raw frame data, plus some camera setting information.

8.3 2D Gaussian

A [1D Gaussian Fit](#), page 91, calculates the 3-parameter, single-variable Gaussian formula that most closely fits a line of data.

A 2D Gaussian Fit calculates the 5-parameter, 2-variable Gaussian formula that most closely represents an area of data.

This more accurately reflects how close the entire laser beam is to being truly Gaussian than two orthogonal 1D Gaussian Fits. However, bear in mind that it is math-intensive and is likely to slow down the BeamStar's update rate.

The example in [Figure 25](#), page 75 is based on the 2D display of [Figure 19](#), page 62.

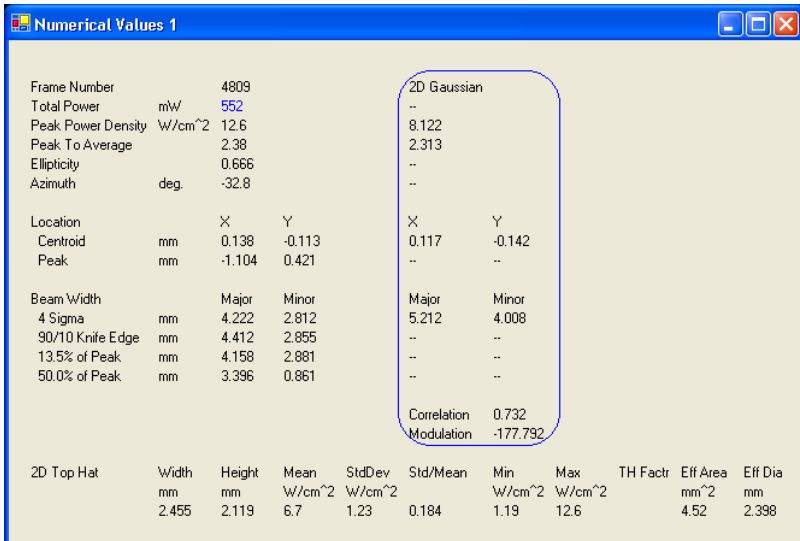


Figure 25: 2D Gaussian fit of the laser beam

8.4 2D Top Hat

Calculated values are dependent on the selected Axis Alignment.

The example in [Figure 26](#), page 76 is based on the 2D display of [Figure 19](#), page 62.

Numerical Values 1									
Frame Number		4809						2D Gaussian	
Total Power	mW	552						--	
Peak Power Density	W/cm ²	12.6						8.122	
Peak To Average		2.38						2.313	
Ellipticity		0.666						--	
Azimuth	deg.	-32.8						--	
Location		X	Y			X	Y		
Centroid	mm	0.138	-0.113			0.117	-0.142		
Peak	mm	-1.104	0.421			--	--		
Beam Width		Major	Minor			Major	Minor		
4 Sigma	mm	4.222	2.812			5.212	4.008		
90/10 Knife Edge	mm	4.412	2.855			--	--		
13.5% of Peak	mm	4.158	2.881			--	--		
50.0% of Peak	mm	3.396	0.861			--	--		
						Correlation	0.732		
						Modulation	-177.792		
2D Top Hat	Width	Height	Mean	StdDev	Std/Mean	Min	Max	TH Factr	Eff Area
	mm	mm	W/cm ²	W/cm ²		W/cm ²	W/cm ²		mm ²
	2.455	2.119	6.7	1.23	0.184	1.19	12.6		4.52
									2.398

Figure 26: 2D Top Hat fit of the laser beam

8.5 Pass/Fail

The **Pass/Fail** option offers setting criteria for any of the numeric results. A measurement that passes the test criteria is displayed in green; one that fails is displayed in red. Results are dependent on the active Axis Alignment mode.

To use the Pass/Fail option:

1. Click the adjacent browse button.

The Numeric Pass/Fail Setup dialog box opens.

	Units	Minimum	Maximum
☒ Total Power	mW	500	800
☒ Peak Power Density	W/cm ²	13	15
☒ Peak To Average	--	2	3
☐ Ellipticity	--	0.000	0.000
☐ Azimuth	deg	0.000	0.000

Location		X	Y
	Units	Minimum	Maximum
☐ Centroid	mm	0.000	0.000
☐ Peak	mm	0.000	0.000

Beam Width		Major	Minor
	Units	Minimum	Maximum
☐ 4 Sigma	mm	0.000	0.000
☐ Knife Edge	mm	0.000	0.000
☐ 13.5%	mm	0.000	0.000
☐ 50%	mm	0.000	0.000

OK Cancel

Figure 27: Numeric Pass / Fail Setup dialog box

2. Select a numeric option.

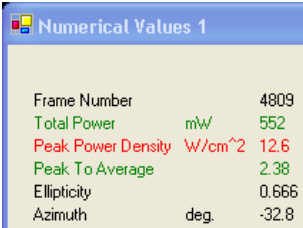
The corresponding **Minimum** and **Maximum** fields are enabled.

3. Type or select the values for the field.

The min/max values entered per option must not be the same. BeamStar will display a message box and will not let you close the main dialog box until correct values are entered for every selected numeric option.

4. Click **OK** when done, or **Cancel** to abort changes.
5. To activate the **Pass/Fail** test, select the option's check box.

The **Pass/Fail** results for the selected criteria are shown in the accompanying insert.



Frame Number		4809
Total Power	mW	552
Peak Power Density	W/cm ²	12.6
Peak To Average		2.38
Ellipticity		0.666
Azimuth	deg.	-32.8



Note: The criteria selections can be saved as part of an *.ooi file (see [Using OOI files](#), page 52).

8.6 Log Data

BeamStar provides a logging function to allow you to save results displayed in the Numeric Values display to a CSV file that can be read easily in Excel or in a text editor.

To log numerical data with time into a text file:

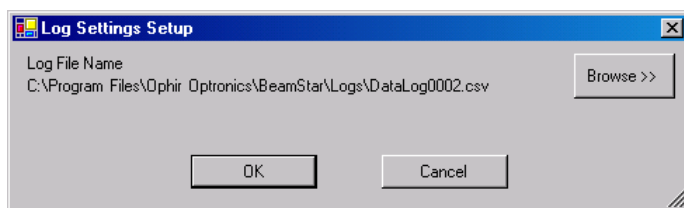
1. Select the data that you want to display and log.
All data selected for display will be logged.
2. In the **Log Data** section, click the blue update.
A list with the following available choices opens:
 - Every update
 - Every second
 - Every 2 seconds
 - Every 5 seconds
 - Every 10 seconds
 - Every 30 seconds
 - Every minute
3. Select the choice that indicates how often you want to update.

From this point on, the program will log the data chosen into a comma-delimited file in the location of the BeamStar program in a subdirectory called **Logs**. The default logging directory will be **...\Ophir Optronics BeamStar\logs**.

The default filename will be **DataLogXXXX.csv**. After each save, the numerical part of the name is incremented by one.

4. Click the browse button to change the location or filename.

The Log Settings Setup dialog box opens.



- a. Click **Browse >>** to open a standard Windows navigation dialog box to change the location and/or file name.

The Log Settings Setup box returns displaying your selection.

- b. Click **OK** to accept, or **Cancel** to abort the change.

The selection appears in the Numerical Values page.

5. Select the check box to enable the logging feature.

[Figure 28](#), page 80 shows a partial section of a log file for the **PulsedYAG4.oor** demo file. Logging was **EveryUpdate** while the video was running. The selected frame, 4809, in the figure is the same data as in the figures of [2D Gaussian](#), page 75.

If you click the adjacent browse button and logging is enabled, the Log Settings Setup dialog box opens indicating that you cannot make changes. Click **Cancel**.



Note: If you changed the location, BeamStar continues to use that location. However, for the next logging event, BeamStar returns to using the default filename format and increments the last digit of the default name by one.

	A	B	C	D	E	F	G	H	I	J
1	Time	Frame Number	Total Power	Peak Power Density	Centroid Location		Peak Location		4 Sigma	
2					X	Y	X	Y	X	Y
3			mW	W/cm ²	mm	mm	mm	mm	mm	mm
4	04:11.1	4847	542.02	11.357	0.13432	-0.09825	-1.08405	0.54945	3.7694	3.31325
5	04:07.3	4809	551.94	12.639	0.13823	-0.1127	-1.10385	0.42075	3.83922	3.27194
6	04:07.5	4811	542.02	11.357	0.13432	-0.09825	-1.08405	0.54945	3.7694	3.31325
7	04:08.1	4817	551.94	12.639	0.13823	-0.1127	-1.10385	0.42075	3.83922	3.27194
8	04:08.7	4823	542.02	11.357	0.13432	-0.09825	-1.08405	0.54945	3.7694	3.31325
9	04:09.3	4829	551.94	12.639	0.13823	-0.1127	-1.10385	0.42075	3.83922	3.27194
10	04:09.5	4831	542.02	11.357	0.13432	-0.09825	-1.08405	0.54945	3.7694	3.31325
11	04:09.7	4833	551.94	12.639	0.13823	-0.1127	-1.10385	0.42075	3.83922	3.27194
12	04:10.0	4836	516.61	11.584	0.10545	-0.10949	-1.00485	0.51975	3.68942	3.28136
13	04:10.2	4838	567.9	12.132	0.15108	-0.11486	-1.01475	0.51975	3.82326	3.27593
14	04:10.4	4840	516.61	11.584	0.10545	-0.10949	-1.00485	0.51975	3.68942	3.28136
15	04:10.7	4843	542.02	11.357	0.13432	-0.09825	-1.08405	0.54945	3.7694	3.31325
16	04:10.8	4844	516.61	11.584	0.10545	-0.10949	-1.00485	0.51975	3.68942	3.28136
17	04:11.0	4846	567.9	12.132	0.15108	-0.11486	-1.01475	0.51975	3.82326	3.27593
18	04:07.6	4812	516.61	11.584	0.10545	-0.10949	-1.00485	0.51975	3.68942	3.28136

Figure 28: Numeric CSV Log file, partial section of the file

9 Profile Graphs

BeamStar FX can profile the power density of a beam as:

- Line Profile

A line profile is a slice through the beam parallel to the x-axis or y-axis.

It may also display the line of pixels along the Major or Minor axis (refer to [Major/Minor Axes](#), page 140).

Two orthogonal (X and Y, Major and Minor) line profiles can be displayed interposed on one graph.

- Sum Profile

A Sum Profile is a profile made by summing parallel lines of pixels. A profile can be one of:

- Columns of pixels (X-Sum Profile)
- Rows of pixels (Y-Sum Profile)
- All lines parallel to the Major Axis
- All lines parallel to the Minor Axis

The Zoom Factor of the 2D Display does not affect the Profile Graphs. To profile a reduced set of data, use [Region of Interest](#), page 133.

By default, two tabs, Profile Graph 1 and Profile Graph 2 and their corresponding plots, are created ([Figure 11](#), page 47). The options ([Figure 29](#), page 82) are the same, thus allowing the user to show the power simultaneously in more than one profile type display. The vertical axis of the Profile Graph plot is always Power Density ranging from zero to some appropriate value. The horizontal axis represents the selection(s) for **Axis** (see [Axis](#), page 84).

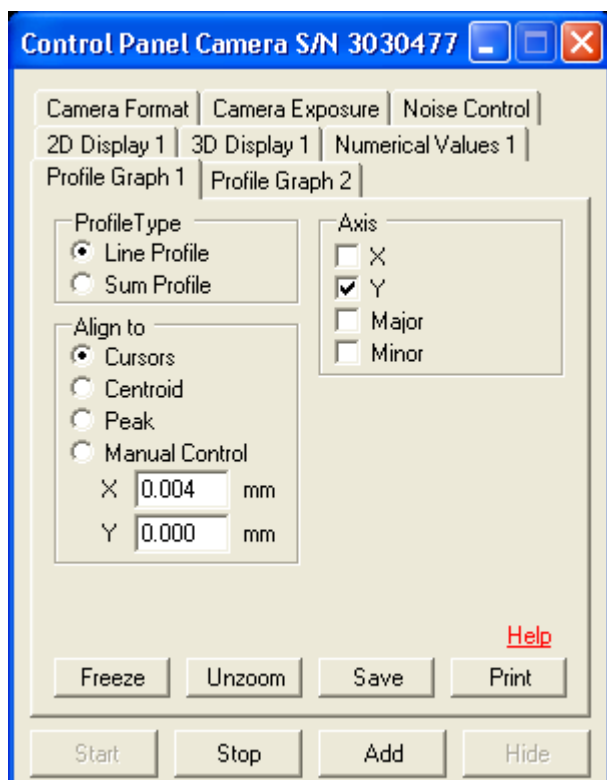


Figure 29: Options of the Profile Graph page

The Profile Graph page is divided into the following sections, as described in [Table 4](#), page 83.

Table 4: Profile Graph control options

Option	Explanation
Profile Type	
Line Profile	For DefaultXY, draws a Line graph plot according to the selections of Align to and Axis . For Beam Axis, draws a Line graph plot according to Axis selections aligned to the Centroid.
Sum Profile	Draws a Sum graph plot according to the Axis selection. Align to is disabled.
Align to (X or Y Line Profiles only)	
Cursors	Aligns the profile to the cursor positions. The zero of the plot for "X" will match the position of the vertical line cursor in the 2D Display. The zero of the plot for "Y" will match the position of the horizontal line cursor. The positions are taken from the 2D Display page setting of the Cursor Alignment . However, to have manual control, Cursor Alignment must be set to Manual , and Cursors must be selected for Markers so that they are visible and can be moved. You can move the intersection (both cursors) by selecting them with the mouse and dragging. The 2D Display's Cursor Alignment control Cursor has no effect on the other Align to options.
Centroid	Draws the profile using the coordinate of the calculated Centroid ("center of mass") as the zero positions of the axis. The coordinate point taken as zero is dependent on the Axis selection. For an "XY" plot, the "X" value is used.
Peak	Draws the profile using the coordinate of the measured peak value as the zero positions of the axis. The coordinate point taken as zero is dependent on the Axis selection. For an "XY" plot, the "X" value is used.
Manual Control	When selected, entered values determine the zero coordinates as if you used the cursors. Even when not selected, the values are updated by the coordinates set by the other Align to options.

Axis	
X	Draws a power density Profile Type , using the Align to selection. If Cursors is selected, moving the horizontal cursor scans Y values along the x-axis. See Line Profiles , page 85.
Y	Draws a power density Profile Type , using the Align to selection. If Cursors is selected, moving the vertical cursor scans Y values along the y-axis. See Line Profiles , page 85.
X, Y selected	Plots the X-Line Profile in black and the Y-Line Profile in green. This option is disabled if Sum Profile is selected.
Major	Draws a power density Profile Type along the Major axis.
Minor	Draws a power density Profile Type along the Minor axis
Major and Minor	Plots Major Profile in black and Minor Profile in green. This option is disabled if Sum Profile is selected.
Control Panel	
Freeze	Toggles on/off updating of the Profile Graph display.
Unzoom	If the Profile Graph has been zoomed, Unzoom returns the display to its full horizontal range. See, for example, Zooming a 1D Gaussian Fit , page 96.
Save	Opens a Windows Save As dialog box to save the current profile as a graphic file (bmp, png, gif, jpg, or tiff format). Default location is the Results folder in the BeamStar program path.
Print	Starts the Windows Print Manager to select an output printer. The full frame of the display is printed. The actual data frame depends on when the printing is initiated.
Help	Opens a Help screen describing mouse functionality within the Profile Graph Display.

9.1 Line Profiles on XY Axes

BeamStar FX displays beam power in watts/cm^2 on the vertical axis and the position in mm on the horizontal axis. This power density is related to the total laser power as set by the user.

The following example uses the `PulsedYAG4.00r` video file to illustrate a Line Profile to scan for power density.

The starting conditions are shown in [Figure 30](#), below. From the 2D Display form, **Markers** were selected for **Peak (+)** and **Centroid (x)**. The cursor lines are placed close to the Centroid location.

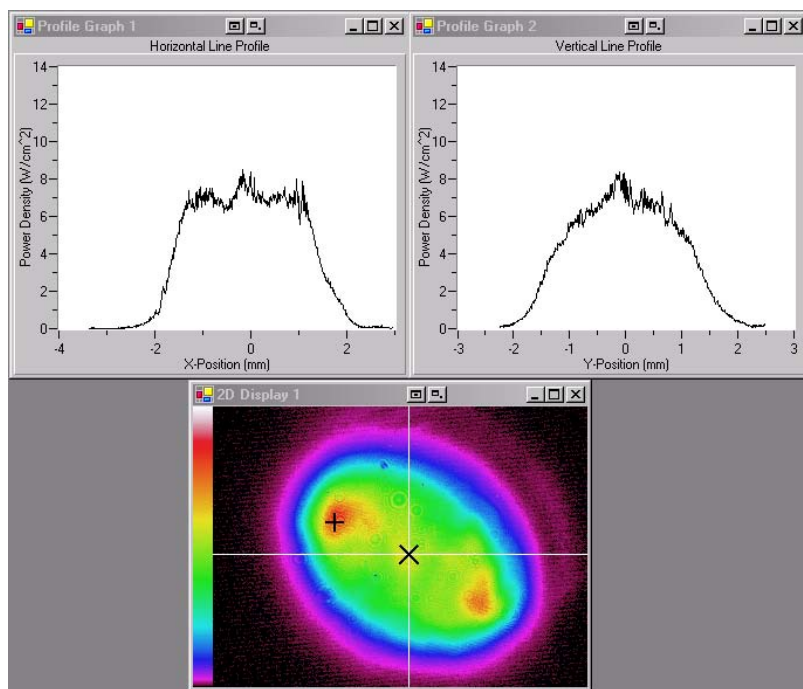


Figure 30: Starting positions for Line Profile example

9.1.1 Axis=X using Align to = Cursors (Profile Graph 1)

In [Figure 31](#), page 86, only the horizontal line has been moved to the lower peak. The values along the X-Position have not moved

(Profile 1). However, the zero point for the Y-Position (Profile 2) has moved downward, producing a larger positive range. The peak for Profile 1 is near 2, as expected. In Profile 2, it is the same peak as in [Figure 30](#), page 85; only its Y-Position has changed.

Therefore, for a profile defined as **Axis=X**, moving the horizontal cursor scans the power density values along the x-axis by displaying the Y values.

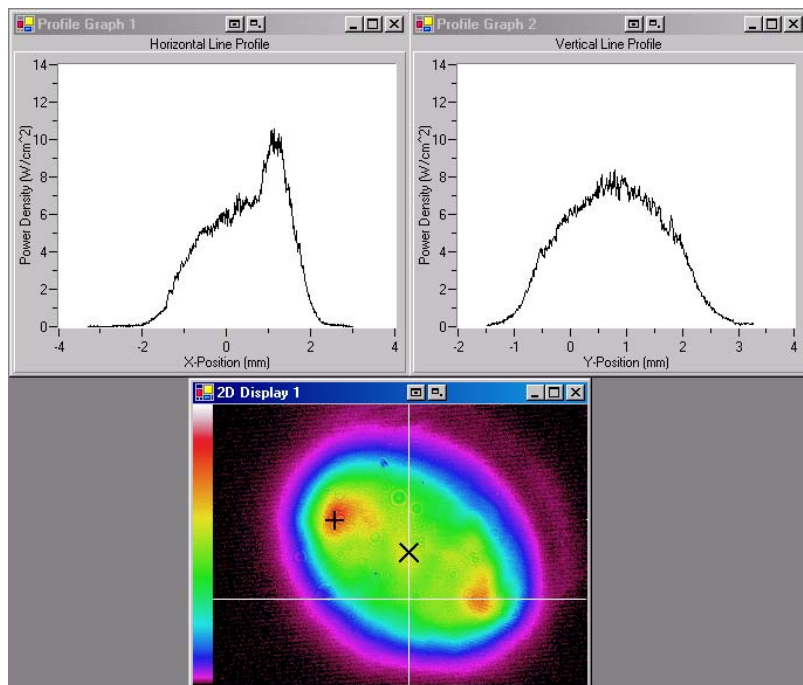


Figure 31: Power Density when Axis = X, Profile 1, lower peak

9.1.2 Axis=Y using Align to = Cursors (Profile Graph 2)

Using the cursor positions of [Figure 30](#), page 85 as the starting point, the example moves the vertical line. Now, the scanning will profile the power density along the Y-axis. The vertical line is moved to the lower peak (see [Figure 31](#), page 86). Profile 1 has remained the same, but its zero location has moved to the right.

Whereas, for Profile 2, the lower peak is displayed having negative values for its Y-Position.

Therefore, for a profile defined as **Axis=Y**, moving the vertical cursor scans the power density values along the y-axis.

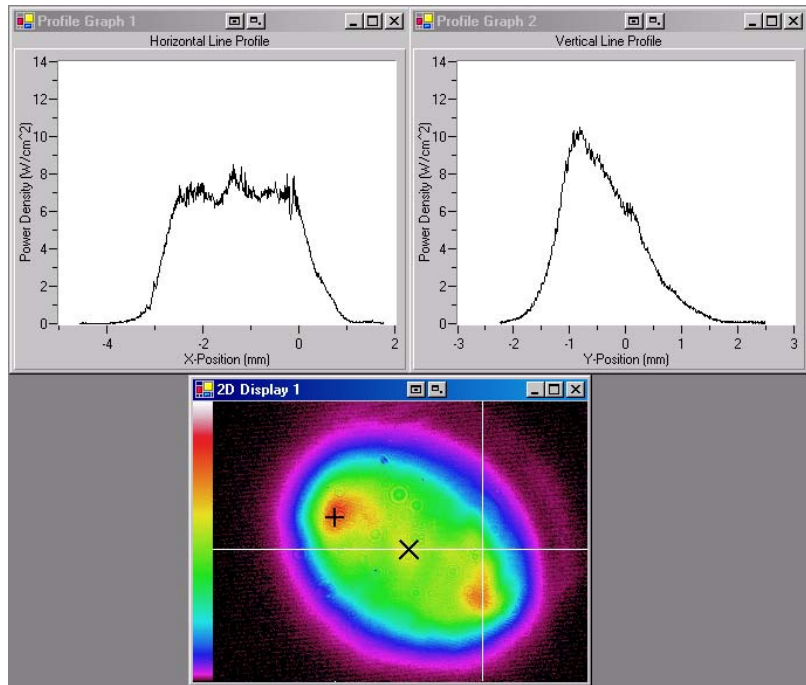


Figure 32: Power Density when Axis = Y, Profile 2, lower peak



Note: On a routine basis, when scanning for one axis, it is not necessary to display the other axis profile.

9.1.3 XY Line Profile using Cursors

The following example uses the `PulsedYAG4.00r` video file to illustrate a XY Line Profile to scan for power density.

To produce an XY Line Profile, select **Axis=X** and **Y**. (The option is disabled if **Sum Profile** is selected.) The X-Line Profile is plotted in black, and the Y-Line Profile is plotted in green.

Options for **Align to** are set to **Peak**.

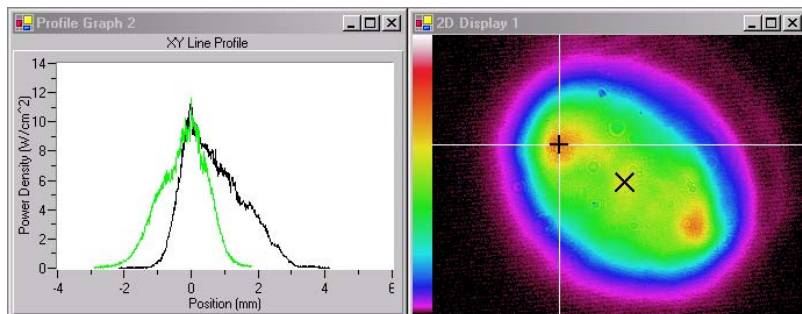


Figure 33: XY Line Profile example

9.2 Sum Profile

[Figure 34](#), page 89 shows the sum profile of the same beam. Note that this profile is smoother since it is a sum which smoothes out irregularities in the beam. For a Sum Profile, **Align to** options are disabled, which is why the cursors have no effect on the two Position axes.

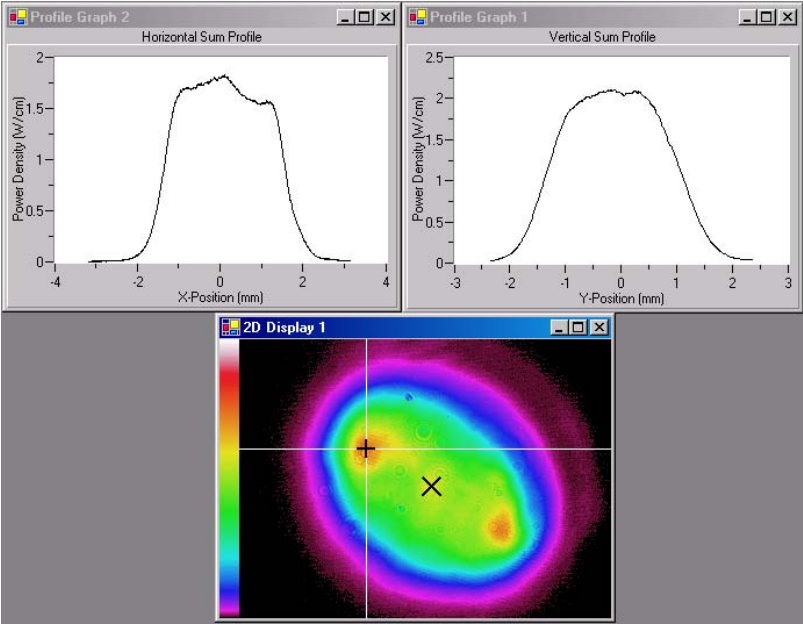


Figure 34: Example of a 2D Sum Profile

9.3 Line Profile on Major/Minor Axes

An example of a Line Profile when Major/Minor is selected is shown in [Figure 35](#), page 89.

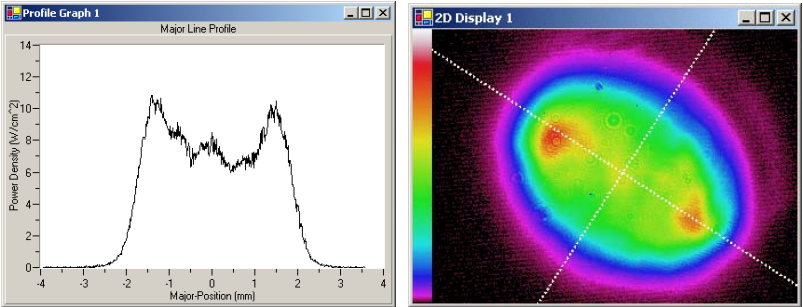


Figure 35: Example of a Line Profile on the Major Axis

9.4 Zooming a Profile Graph

To zoom a Profile Graph:

1. Place the mouse at the edge of the zoom area.
2. Click the right mouse button.

A black line is drawn to mark that edge of the zoom area.
3. Drag the mouse to the other edge of the zoom area.

A second black line is drawn to mark the mouse movement.
4. Release the right mouse button.

The Line Profile zooms in on the area between the two lines.
5. To unzoom, click the **Unzoom** button on the appropriate Control Tab in the Control Panel.

10 1D Gaussian Fit

BeamStar calculates a best-fit Gaussian of the beam (Line or Sum profiles) and provides a selectable readout of numerical information of the fit. The user can also set pass/fail criteria. Multiple instances of the Gaussian fit can be executed, with each instance having its own settings.

The Zoom Factor of the 2D Display does not affect the calculation or display of the 1D Gaussian fit. To perform a 1D Gaussian fit on a reduced set of data, use [Region of Interest](#), page 133.

To display the beam data in a Gaussian fit:

1. Click **Add > 1D Gaussian Fit**.

A **1D Gaussian Fit** page ([Figure 36](#), page 92) is added to **Control Panel**, and the display window opens ([Figure 37](#), page 92). By default, **Line Profile** and **Axis=X** are selected. The other options are selected for the example.

Refer to [Table 6](#), page 100 for an explanation of the options.

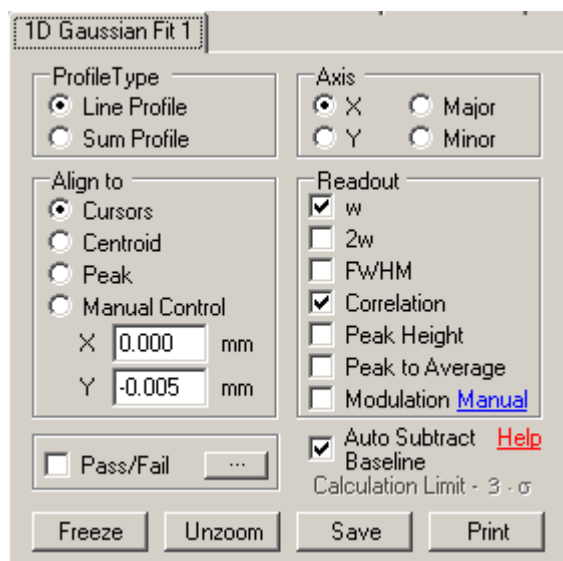


Figure 36: 1D Gaussian Fit page

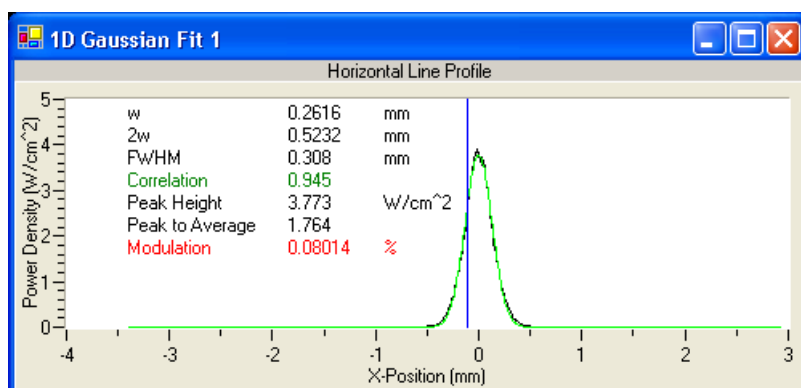


Figure 37: 1D Gaussian Fit with Pass/Fail option active

Table 5: 1D Gaussian Fit page options

Option	Explanation
Profile Type	Refer to Profile Graphs , page 81 and Table 4 , page 83.
Align to	Refer to Profile Graphs , page 81 and Table 4 , page 83.
Axis	Refer to Profile Graphs , page 81 and Table 4 , page 83.
Readout	
w	Beam waist dimension defined as the half width of the profile at $1/e^2$ of the maximum beam intensity.
2w	Full width of the profile as defined above.
FWHM	Full width of the profile at half the maximum intensity.
Correlation	Correlation between the beam profile and an ideal Gaussian beam.
Peak Height	Height of the correlated ideal Gaussian beam in units of watts/cm ² .
Peak to Average	Result of Peak Height divided by Average, where Average is the average of all the points that are at least $1/e^2$ (~13.5%) of the peak.
Modulation	Displays the error (%) of the Gaussian fit at the selected point. Points available for Modulation range between the points bound by FWHM. When selected, a blue vertical appears at the location determined by the selection: Manual user selected point. Best point of best fit to the Gaussian plot. Worst point of worst fit to the Gaussian plot. You can use the mouse to zoom in on any selected horizontal range; refer to Zooming a 1D Gaussian Fit, page 96.

Option	Explanation
Auto Subtract Baseline	Automatically subtracts any zero bias on the baseline. The procedure fails if the algorithm cannot determine a baseline. For example, a failure occurs if the beam covers the area of the picture and there is no dark space at the edges.
Pass/Fail	See Step 655H7 , page 99.
Check box	Select to have criteria active. Criteria that pass are displayed in green font; those that fail are in red font.
Browse button	Click to open the dialog box to set Pass/Fail criteria.
Page buttons	
Freeze/UnFreeze	Toggles on/off updating of the 1D Gaussian display and the updating of information and calculations.
Unzoom	If the Gaussian Fit display has been zoomed, returns the display to its full horizontal range. Refer to Zooming a 1D Gaussian Fit , page 96.
Save	Opens a standard Windows Save As dialog to save the current profile either as a graphic file (bmp, png, gif, jpg, or tiff format), CSV file, or fixed-column text file. Saves the Readout results and the graphical data.
Print	Starts the Windows Print Manager to select an output printer. The full frame of the display is printed. The actual data frame depends on when the printing is initiated.
Help	Opens a Help screen describing mouse functionality within the 1D Gaussian Fit Display.

2. In **Profile Type**, select the **Line Profile** or **Sum Profile**.
3. In **Align to**, select where to align the profile.
4. In **Axis**, select one of the following profiles: **X**, **Y**, **Major**, or **Minor**.

If you want to measure the fit along more than one axis, open additional instances of **1D Gaussian Fit** profiles.

5. In **Readout**, select the desired options.
6. If using **Modulation** in manual mode, click the option box and move the vertical blue line to a location on the curve.

Range is restricted to the set of points within the FWHM of the fit.

7. Set **Pass/Fail** options if desired.
 - a. Click the browse button to open the dialog box for setting criteria.

Note that the maximum and minimum settings for a given option cannot be equal.

	Units	Minimum	Maximum
☐ w	mm	0.000	0.000
☐ 2w	mm	0.000	0.000
☐ FWHM	mm	0.000	0.000
☒ Correlation	--	0.900	0.990
☐ Peak Height	W/cm ²	0.000	0.000
☐ Peak to Average	--	0.000	0.000
☒ Modulation	%	0.000	0.050

OK Cancel

- b. Click OK.
- c. Select the check box to activate.

In the example of [Figure 37](#), page 92, the **Correlation** value passes and the **Modulation** value fails.

10.1 Zooming a 1D Gaussian Fit Graph

To zoom a 1D Gaussian Fit Graph:

1. Place the mouse at the edge of the zoom area.
2. Click the right mouse button.
A black line is drawn to mark that edge of the zoom area.
3. Drag the mouse to the other edge of the zoom area.
A second black line will be drawn to mark the mouse movement.
4. Release the right mouse button.
The 1D Gaussian Fit display is zoomed in on the area between the two lines.
5. To unzoom, click the **Unzoom** button on the appropriate Control Tab in the Control Panel.

11 1D Top Hat Fit

BeamStar calculates a Top Hat characterization of the beam (Line or Sum profiles) based on a user-defined range, and provides a selectable readout of numerical information of the fit. The user can also set pass/fail criteria. Multiple instances of the Top Hat fit can be executed with each instance having its own settings.

The Zoom Factor of the 2D Display does not affect calculation or display of the 1D Top Hat fit. To perform a 1D Top Hat fit on a reduced set of data, use [Region of Interest](#), page 133.

To display the beam data in a Top Hat fit:

1. Click **Add > 1D Top Hat Fit**.

A **1D Top Hat Fit** page ([Figure 38](#), page 98) is added to Control Panel, and the display window opens ([Figure 39](#), page 98). By default, **Line Profile** and **Axis=X** are selected. The other options are selected for the example.

Refer to [Table 8](#), page 113 for an explanation of the options.

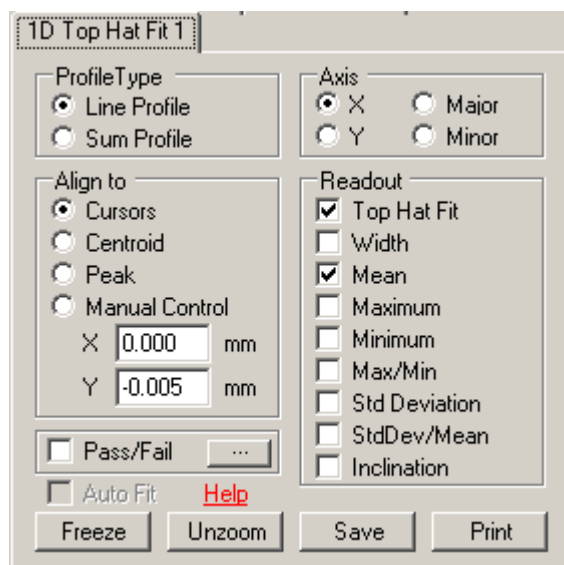


Figure 38: 1D Top Hat fit page

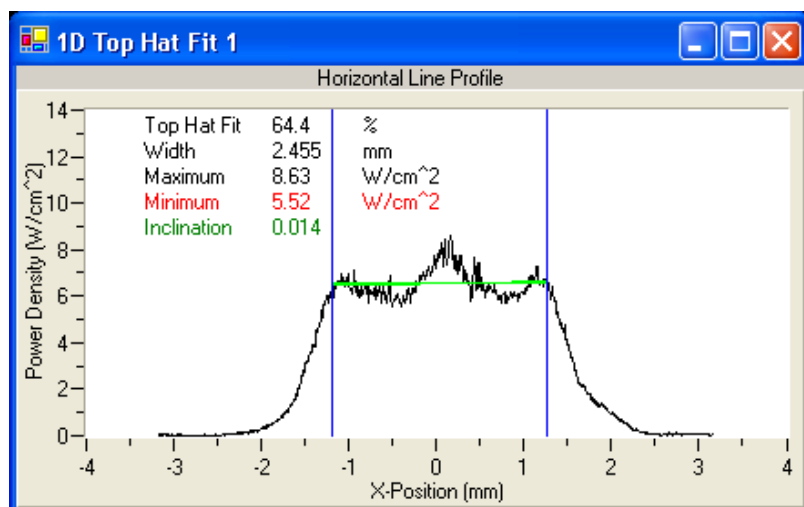


Figure 39: Top Hat fit example with Pass/Fail option active

2. In **Profile Type**, select **Line Profile** or **Sum Profile**.
3. In **Align to**, select where to align the profile.
4. In **Axis**, select one of the following profiles: **X**, **Y**, **Major**, or **Minor**.

If you want multiple Top Hat profiles, open additional instances of **1D Top Hat** profiles.

5. Adjust the position of the vertical blue lines that set the ends for the calculation of the **Readout** options.

If **Align to** = **Cursors** on the Top Hat page, and if on that page **Cursor Alignment** is set to **Manual**, the cursor position on the 2D Display will determine the results.

6. In **Readout**, select the desired options.
7. Set **Pass/Fail** options if desired.
 - a. Click the browse button to open the dialog for setting criteria.



Note: The maximum and minimum settings for a given option cannot be equal.

	Units	Minimum	Maximum
☐ Top Hat Fit %	%	0.000	0.000
☐ Width	mm	0.000	0.000
☐ Mean	W/cm ²	0.000	0.000
☐ Maximum	W/cm ²	0.000	0.000
☒ Minimum	W/cm ²	4.000	5.000
☐ Max / Min	--	0.000	0.000
☐ Std Deviation	W/cm ²	0.000	0.000
☐ StdDev / Mean	--	0.000	0.000
☒ Inclination	--	0.000	0.020

OK Cancel

- b. Click **OK**.

- c. Select the check box to activate.

The results in [Figure 39](#), page 98 show that the **Inclination** value passes and the **Minimum** value fails.

Table 6: 1D Top Hat page options

Option	Explanation
Profile Type	Refer to Profile Graphs , page 81 and Table 4 , page 83.
Align to	Refer to Profile Graphs , page 81 and Table 4 , page 83.
Axis	Refer to Profile Graphs , page 81 and Table 4 , page 83.
Readout	
Top hat fit %	Correlation between the ideal Top Hat as delineated by the blue lines, horizontal green line, and the actual profile. You can optimize the top hat fit by dragging the blue lines back and forth with the mouse until the value is maximized.
Width (or Height)	Width of the fitting profile as defined by the distance between the two blue lines.
Mean	Average beam intensity in the region between the blue lines.
Maximum	Maximum beam intensity in the region between the blue lines.
Minimum	Minimum beam intensity in the region between the blue lines.
Max/Min	Maximum as defined above divided by the minimum as defined above.
Std Deviation	Standard deviation of the profile from the mean in the region between the two blue lines.
Std Dev/Mean	Standard deviation value divided by the mean beam intensity. The lower this number is, the closer the beam comes to an ideal flat top profile.

Option	Explanation
Inclination	Slope of the best fit inclined line between the blue lines. This slope is normalized such that a slope value of 1 indicates that the left edge is at 0 and right edge is at twice the average.
Pass/Fail	See Step 655H7 , page 99
Check box	Select to have criteria active. Criteria that pass are displayed in green font; those that fail are in red font. See Figure 39 , page 98.
Browse button	Click to open the dialog box to set Pass/Fail criteria.
Page buttons	
Freeze/UnFreeze	Toggles on/off updating of the Top Hat display and the updating of information and calculations.
UnZoom	If the 1D Top Hat display has been zoomed, returns the display to its full horizontal range. See Zooming a 1D Top Hat Fit
Save	Opens a standard Window Save As dialog in which the options are graphic files, CSV file, or fixed-column text file.
Print	Starts the Windows Print Manager to select an output printer. The full frame of the display is printed. The actual data frame depends on when the printing is initiated.
Help	Opens a Help screen describing mouse functionality within the 1D Top Hat Display.

11.1 Zooming a 1D Top Hat Fit Graph

To zoom a 1D Top Hat Fit Graph:

1. Place the mouse at the edge of the zoom area.
2. Click the right mouse button.

A black line is drawn to mark that edge of the zoom area.

3. Drag the mouse to the other edge of the zoom area.

A second black line will follow the mouse movement.

4. Release the right mouse button.

The 1D Top Hat display will be zoomed in on the area between the two lines.

5. To unzoom, press the **Unzoom** button on the appropriate Control Tab in the Control Panel.

12 Report Generator

The Report Generator tool generates a formatted file describing the performance of the laser under test. Reports can be generated in Text only, Graphic only, or mixed text and graphic formats.

There are two methods to start the Generator:

- Click its icon .
- Select the feature from **File > Generator Report**.

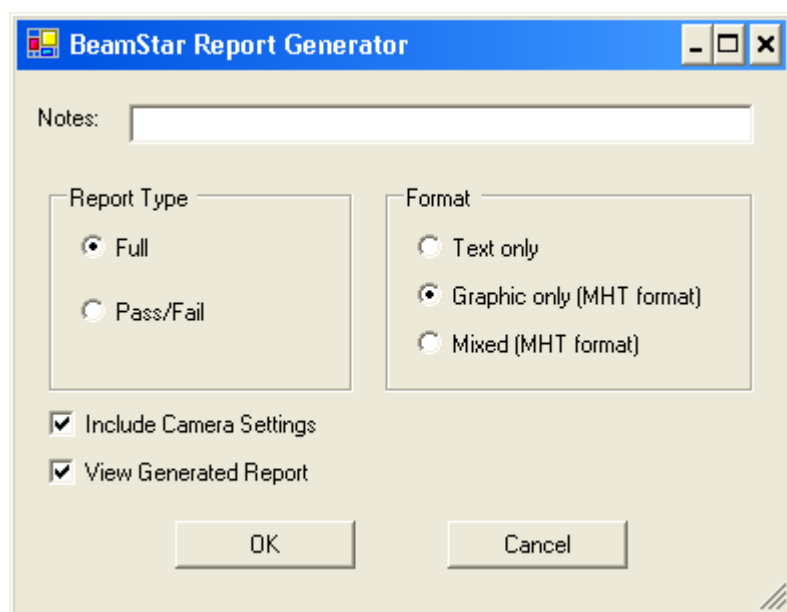


Figure 40: Report Generator dialog box

Table 7: Options of the Report Generator

Option	Explanation
Notes	Descriptive text entered by the user.
Report Type	
Full	Includes all information from all Active Displays.
Pass/Fail	Includes information from Displays with enabled Pass/Fail Test criteria.
Format	With either Report Type
Text only	Generates report in ASCII text format.
Graphic only (MHT format)	Generates a report that includes images of all Active Displays and their associated Control Panel Tab Pages. The report can be opened with a Web browser.
Mixed (MHT format)	Generates report that includes images of all Active Displays and their associated Control Panel tab pages. A section with all readouts in a text-based layout is included at the bottom of the report. The report can be opened with any Web browser.
Include Camera Settings	When checked, camera settings are included in the report.
View Generated Report	After clicking OK , automatically opens either the Text file (Notepad) or the MHT..
OK	Creates the performance file.
Cancel	Closes the dialog box without any performance information being generated.

Performance Report				
Date: 18/05/2005				
Time: 18:06:45				
Generated by: BeamStar 1.10				
Camera: BC102				
Notes:				
=====				
Numeric Data				
=====				
Numerical Values 1				

Frame Number		4809		
Total Power	mW	552		
Peak Power Density	W/cm^2	12.6		
Peak To Average		2.38		
Location		X	Y	
Centroid	mm	0.138	-0.113	
Peak	mm	-1.104	0.421	
Beam Width		X	Y	
4 Sigma	mm	3.861	3.290	
90/10 Knife Edge	mm	4.010	3.367	
13.5% of Peak	mm	3.653	3.138	
50.0% of Peak	mm	2.435	1.356	
=====				
Camera Settings				
=====				
Video Format:		640x480		
Number of bits:		10		
Frame Rate (fps)		30.0 fps		
Shutter Time (sec)		0.0030625		
Gain (dB)		9.90594573319914		

Figure 41: Report for Full with Text only

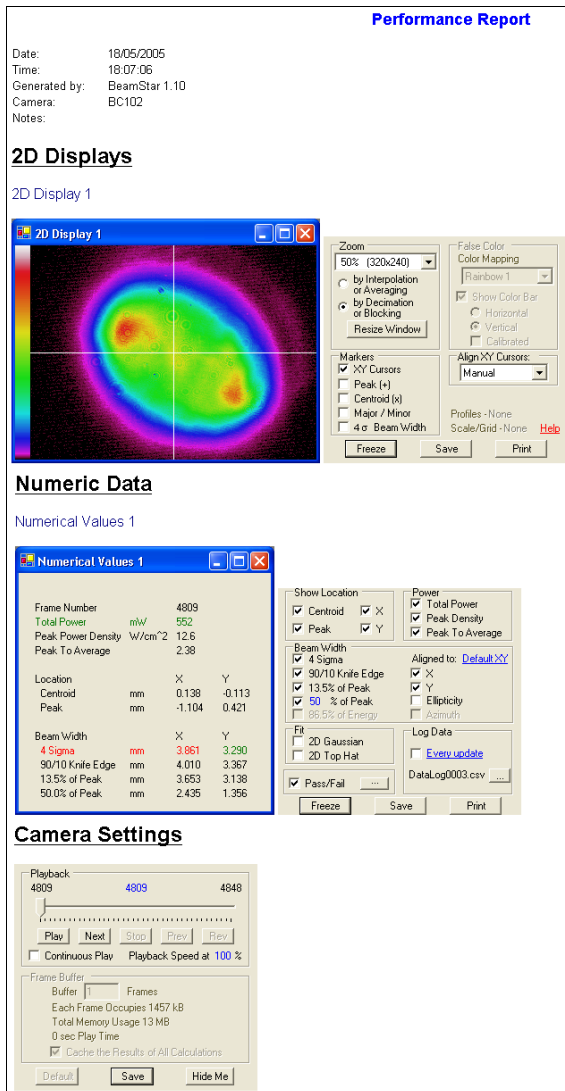


Figure 42: Full Report with Graphics only

Graphic section same as Full with Graphics only

Numeric Data

Numerical Values 1

Frame Number		4809	
Total Power	mW	552	
Peak Power Density	W/cm ²	12.6	
Peak To Average		2.38	
Location		X	Y
Centroid	mm	0.138	-0.113
Peak	mm	-1.104	0.421
Beam Width		X	Y
4 Sigma	mm	3.861	3.290
90/10 Knife Edge	mm	4.010	3.367
13.5% of Peak	mm	3.653	3.138
50.0% of Peak	mm	2.435	1.356

Camera Settings

Video Format:	640x480
Number of bits:	10
Frame Rate (fps)	30.0 fps
Shutter Time (sec)	0.0030625
Gain (dB)	9.90594573319914

Figure 43: Full Report with Text and Graphics showing only the Text

Pass/Fail Report					
Date: 18/05/2005					
Time: 18:03:22					
Generated by: BeamStar 1.10					
Camera: BC102					
Notes:					
=====					
Numeric Data					
=====					
Numerical Values 1					
Total Power	mw	552		Results	
4 Sigma	mm	3.861	3.290	Pass	
				Fail	Pass
=====					
Camera Settings					
=====					
Video Format:	640x480				
Number of bits:	10				
Frame Rate (fps)	30.0 fps				
Shutter Time (sec)	0.0030625				
Gain (dB)	9.90594573319914				

Figure 44: Pass/Fail with Text only

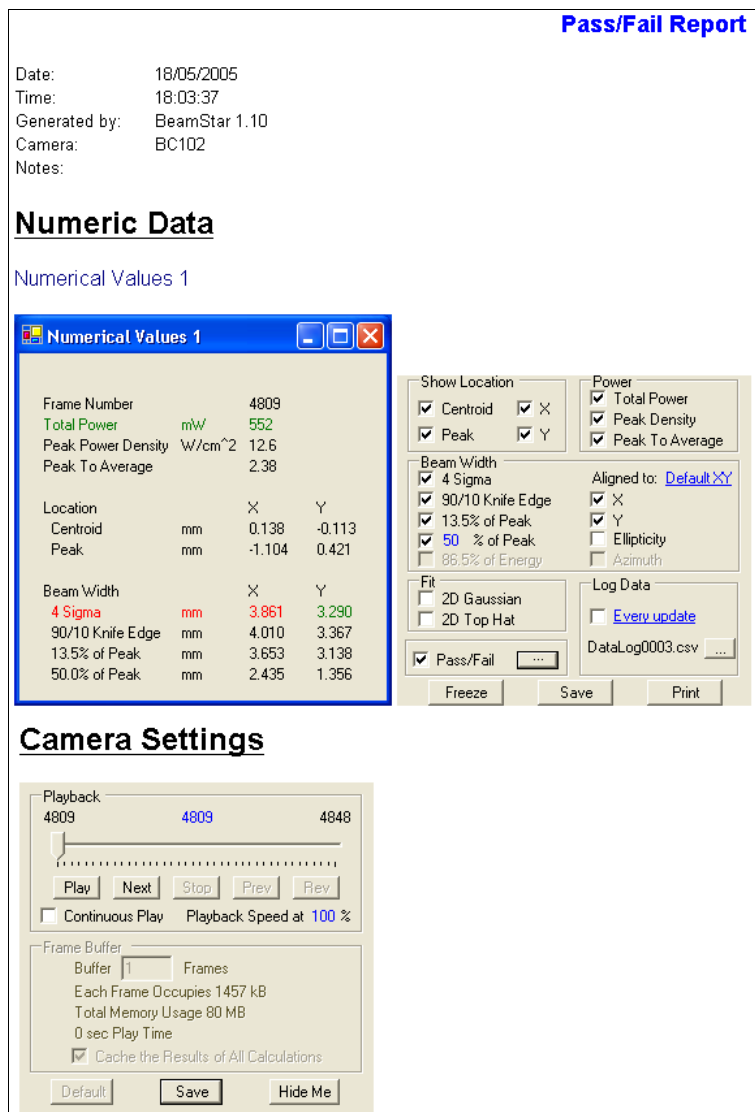


Figure 45: Pass/Fail with Graphics only

Graphic section same as Pass/Fail with Graphics only

Numeric Data

Numerical Values 1

Total Power	mW	552			Results
4 Sigma	mm	3.861	3.290		Pass
					Fail Pass

Camera Settings

Video Format:	640x480
Number of bits:	10
Frame Rate (fps)	30.0 fps
Shutter Time (sec)	0.0030625
Gain (dB)	9.90594573319914

Figure 46: Pass/Fail with Text and Graphics showing only the Text

13 Beam Wander

Beam Wander plots the change in centroid position over time.

The position can be plotted in microns or microradians.

Each position plotted on the display also updates the readout section of the display that lists position and statistical information.

To start Beam Wander:

1. Click **Add** on the **Control Panel**.

Alternatively, click its icon  on the toolbar.

The Add form opens.

2. Click **Beam Wander**.

The Beam Wander page is added to the Control Panel and its display window opens. Refer to [Table 9](#), page 123 for an explanation of the options and controls.



Figure 47: Beam Wander page (default)

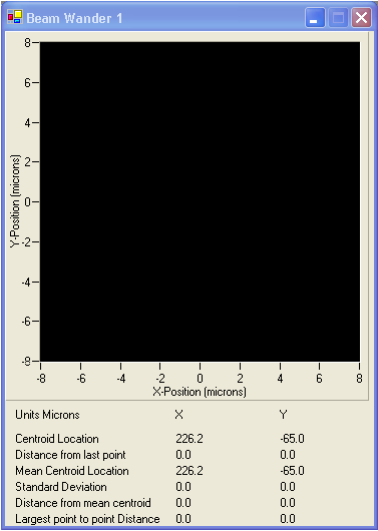


Figure 48: Beam Wander display (default)

See [Table 9](#), below for an explanation.

Table 8: Beam Wander page options

Option	Explanation
Readout-Centroid	Uses units selected by Microns/Microradians. Values are for the current period.
Location	The position of the most recent data point.
Mean	The average of the location values.
Std Dev	The standard deviation of the Mean of the Location values.
Readout-Distance	Uses units selected by Microns/Microradians. Values are for the current period.
From last centroid	The distance between the most recent data point and the one before it.
From mean centroid	The distance between most the recent data point and the Mean.
Max point to point	The distance between the furthest two points in the entire data set.
Tracking	
Limit	Sets the time length that recordings will be made using Period and Rate. Limit must be equal to or larger than Period. BeamStar will force the Limit unit to be equal to or larger than the Period unit.. Click the blue font text to change units.
Period	Sets the time length for Readout calculation, where data is collected based on Rate value. Period must be equal to or less than Limit. When a Period ends, the graph and data set are cleared. Tracking continues until the Tracking Limit is reached. Click the blue font text to change units.

Option	Explanation
Rate	The rate at which data is collected, from a minimum of 1 second to a maximum rate of 60 seconds. The slide button cannot be moved beyond a value greater than that of Period. However, the left extreme position of the slide button results in EveryUpdate. This setting allows data to be collected at the fastest rate for each Period, based on system resources. However, the number of points and their interval will vary.
Controls	See AutoScale, Center, and Decenter of the Beam Wander Display , page 117.
Clear	Clears the Beam Wander graph and readouts.
Center	Disabled if Auto Scale is checked. When clicked, uses the coordinates of Mean Centroid Location values to set the center of the display and 4σ to set their axis limits. Whereas Auto Scale continuously relocates the axis and their limits, Center requires the manual click of the button to update each axis.
Decenter	Sets each axis to the dimension of the camera. Is enabled when Auto Scale is cleared. Disabled after clicking; enabled if Center is clicked.
Auto Scale	Continuously fixes the center of the display area to be the coordinates of Mean Centroid Location values. The axis limits are continuously updated to the minimum and maximum centroid values that were measured. If selected, disables Center and Decenter. When cleared, enables Center.

Option	Explanation
Microns/Microradians	Click the blue text to toggle to the other option. Microns represent linear distances from the camera's center position. Microradians represent angular distances from the center position (see Microradians , page 116).
Browse button	Enabled when Microradians is enabled. Click to enter distance between the camera and the laser surfaces (see Microradians , page 116).
Log Data	
Log	Clicking resets the display information and starts the logging process. Clearing terminates a logging at that instance. Logging continues recording the passage of Periods until the Limit , even if Freeze or Stop camera was initiated.
Type	Log file is either CSV or text; click the current type to select the other type.
File name and Browse button	Click to change the location and/or file name of the next logging file. The default name is WL3100022_wxyz.Type. The numbers start at 0001 and are incremented by one each time the default name is used. The button and the logging operation are similar to that of Numerical Values (see Log Data , page 72 in Table 3 , page 70).
Page Buttons	
Freeze/Unfreeze	Toggles on/off updating of the Beam Wander display and the updating of information and calculations. See also Log Data , page 78.
Save	Saves the Beam Wander display as a graph in user selected format of bmp, png, gif, jpg, or tiff.

Option	Explanation
Print	Starts the Windows Print Manager to select an output printer. The full frame of the display is printed. The actual data frame depends on when the printing is initiated.

13.1 Microradians

BeamStar can also report the dispersion from the centroid mean location in microradians.

To use this feature, the user must supply the linear distance between the camera's outer surface and that of the laser source.

The linear distance, in meters, is used in the following formula to calculate L, the total distance to the camera's surface.

$$L = ((\text{Distance from Laser to Camera Surface}) + (\text{Distance from Camera Surface to CCD Array}) * .001).$$

The first distance term is supplied by the user.

The second distance term is known for each camera.

Microradians equal X/L , where L is defined above and X is the distance in microns that the centroid moved across the camera.

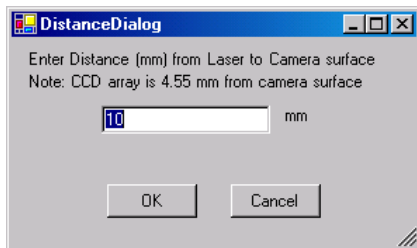
To enter the distance:

1. If Microradians is not selected, click **Microns** to select it.

The adjacent browse button is enabled.

2. Click the browse button.

The Distance dialog box opens.



3. Type the distance, in millimeters, from the laser to the camera surface, and click **OK**.

The calculated value is updated and remains enabled while Microradians is active.

To enter a new value for the distance, repeat this procedure.

13.2 AutoScale, Center, and Decenter of the Beam Wander Display

Below are images of the same set of data displayed in AutoScaled mode, Centered, and Decentered. Notice how the AutoScaled display is spread out over the entire display area, the Centered display is more condensed, and how the Decentered display is condensed into just one point.

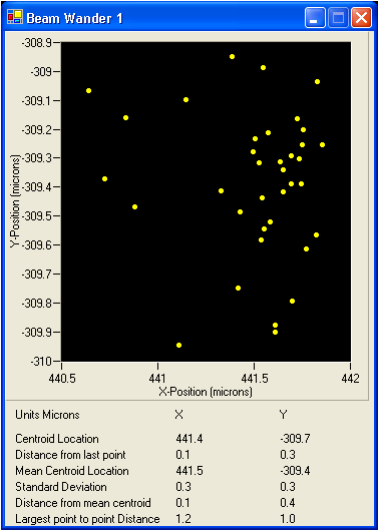


Figure 49: Beam Wander display set to AutoScale

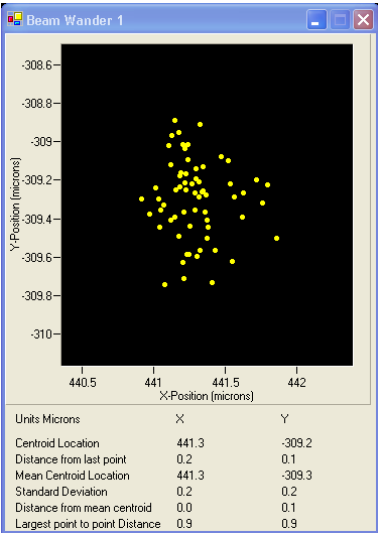


Figure 50: Beam Wander display set to Center

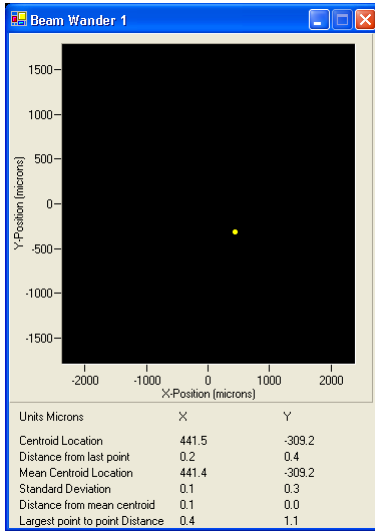


Figure 51: Beam Wander display set to Decenter

13.3 Log Data

BeamStar provides a logging function that enables you to save results displayed in the BeamWander display to a CSV file, which can easily be read in Excel or in a text editor.

To log Beam Wander Readout data into a text file:

1. Select the data that you want to display and log.
All data selected for a display will be logged.
2. Set **Tracking** parameters and **Control** method.
3. In the Log Data section, click the blue text.
4. Select either **Type csv** or **Type Text**.

For this example, **Type csv** was selected.



Note: The logging is for a different camera than that shown in [Figure 49](#), page 118.

From this point on, the program will log the data chosen into a comma-delimited file in the location of the BeamStar program in a subdirectory called **Logs**.

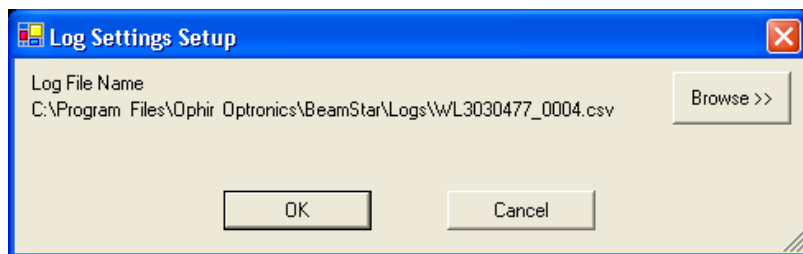
The default logging directory will be `...\Ophir Optronics BeamStar\logs\`.

The default filename will be `WLXXXX.csv`.

After each save, the numerical part of the name is incremented by one.

5. Click the browse button to change the location or filename.

The Log Settings Setup dialog box opens.



- a. Click **Browse >>** to open a standard Windows navigation dialog box to change the location and/or file name.

The Log Settings Setup dialog box returns, displaying your selection.

- b. Click **OK** to accept, or **Cancel** to abort the change.

The selection appears in the Numerical Values page.

6. Select the check box to enable the logging feature.

[Figure 52](#), page 121 shows a partial section of a log file. Although the Tracking Rate was set to 1 second, the recorded interval times may vary due to system resources.

If you click the adjacent browse button and logging is enabled, the Log Settings Setup dialog box opens, indicating that you cannot make changes. In such a case, click **Cancel**.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Time		Centroid		Distance from last	Mean		Std Dev.		Distance from mean		Largest Point to Point			
2			X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	Distance
3			Microns	Microns	Microns	Microns	Microns	Microns	Microns	Microns	Microns	Microns	Microns	Microns	
4	49 50.7		142.3	105.4	0	0	142.3	105.4	0	0	0	0	0	0	0
5	49 51.9		141.8	105.5	0.5	0.1	142.1	105.5	0.3	0.1	0.2	0	0.5	0.1	
6	49 52.9		143.8	107.4	1.9	1.9	142.7	106.1	1	1.1	1.1	1.3	1.9	2	
7	49 53.9		141.6	105	2.2	2.3	142.4	105.8	1	1.1	0.8	0.8	2.2	2.3	
8	49 55.0		141.4	106.4	0.2	1.4	142.2	106	1	1	0.8	0.5	2.4	2.3	
9	49 56.1		142	106.5	0.6	0.1	142.2	106	0.9	0.9	0.2	0.4	2.4	2.3	
10	49 57.1		141.6	106.7	0.4	0.2	142.1	106.1	0.8	0.8	0.5	0.6	2.4	2.3	
11	49 58.1		141.3	107.2	0.2	0.4	142	106.3	0.8	0.9	0.6	0.9	2.5	2.3	
12	49 59.3		142.1	105.4	0.8	1.8	142	106.2	0.8	0.9	0.1	0.8	2.5	2.3	
13	50 00.4		140.7	105.1	1.4	0.3	141.9	106.1	0.8	0.9	1.1	0.9	3	2.3	
14	50 01.1	Period Ended													
15	50 01.1	Summary					141.9	106.1	0.8	0.9			3	2.3	
16															
17															
18	50 01.1	New Period													
19	50 01.0		142.4	105.2	0	0	142.4	105.2	0	0	0	0	0	0	
20	50 02.2		143.1	105.8	0.7	0.7	142.7	105.5	0.5	0.5	0.4	0.3	0.7	0.7	
21	50 03.2		141.8	105.6	1.3	0.2	142.4	105.5	0.7	0.3	0.6	0.1	1.3	0.7	
22	50 04.3		143	104.5	1.2	1.1	142.6	105.3	0.6	0.6	0.5	0.8	1.3	1.3	
23	50 05.4		143.8	107.7	0.7	3.2	142.8	105.7	0.7	1.2	0.9	1.9	1.9	3.2	
24	50 06.5		141.8	106.2	1.9	1.5	142.7	105.8	0.8	1.1	0.8	0.3	1.9	3.2	
25	50 07.6		141	105.7	0.9	0.5	142.4	105.8	1	1	1.4	0.1	2.8	3.2	
26	50 08.6		141.8	105.7	0.8	0	142.3	105.8	0.9	0.9	0.6	0.1	2.8	3.2	
27	50 09.6		143.2	106.6	1.5	0.9	142.4	105.9	0.9	0.9	0.8	0.8	2.8	3.2	
28	50 11.1	Period Ended													
29	50 11.1	Summary					142.4	105.9	0.9	0.9			2.8	3.2	

Figure 52: BeamWander Log file, partial section of the file

14 The 3D Display

The BeamStar FX output includes a 3D display of the beam.

The 3D display parameters are adjustable by the user, but it is best to leave most of them at their default values.

14.1 Showing a 3D Display

To show a 3D display:

1. If a 3D display window is not available, click **Add** and select **3D Display**.
2. Click the **3D Display** tab to bring its page to the front.

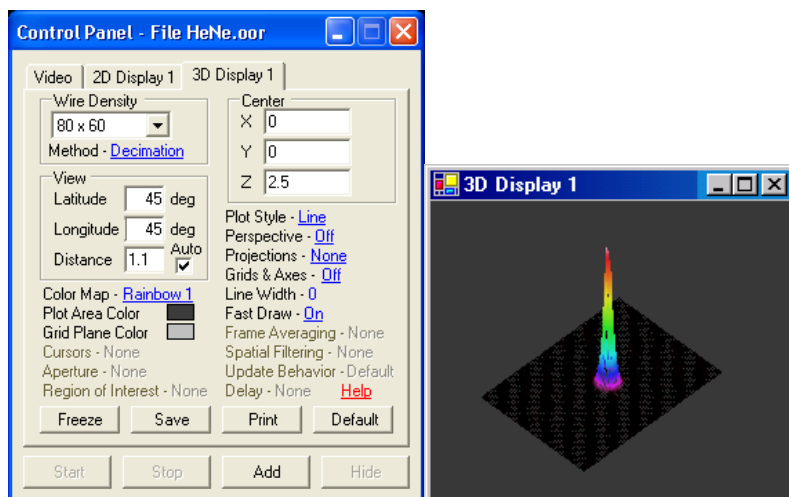


Figure 53: 3D page and its display (default) example

Table 9: 3D Display options

Option	Explanation
Wire Density	Determines the number of vertical and horizontal values that are used to represent the shape of the beam. Values are selected from a drop-down list box. Possible values are: • 40 x 80 • 64 X 48 • 80 x 60 (default) • 160 x 120 • 320 x 240 • 640 x 480
Method	Determines the method to calculate points and lines when displaying the beam in 3D. The methods are similar to those of the 2D Display for the Zoom option. See Zoom, page 57.
Decimation	Points are removed according to the Wire Density value.
Averaging	Points are averaged according to the Wire Density value.
View	Determines the rotation and tilt of the display, and sets the distance from the beam. Values can be entered manually. Otherwise, the values refer to the default settings or to those set by the Mouse/Keyboard operations. Refer to Mouse/Keyboard control, page 125.
Latitude	Tilt.
Longitude	Rotation.
Distance	Default value is 1.1.
Auto	Selected, returns Distance to 1.1.

Option	Explanation
Color Map	Color format for the beam. Click the existing format (blue) to select one of the following: • Rainbow 1 • Color Spectrum • Gray Scale • None • Shaded
Plot Area Color	Sets the background color. To choose a color, click the adjacent current colored square, which opens a standard Windows palette dialog.
Grid Plane Color	Sets the Grid plane color. To choose a color, click the adjacent current colored square, which opens a standard Windows palette dialog.
Center	Locate the center in the display window. Values may be entered manually. Otherwise, the values refer to the default settings or to those set by the Mouse/Keyboard operations. Refer to Mouse/Keyboard control, page 125.
Plot Style	Click the current style to select one of the following: • Point • Line • LinePoint • HiddenLine • ContourLine • Surface • SurfaceLine • SurfaceContour • SurfaceNormal
Perspective	Off/On

Option	Explanation
Projections	Creates a 2D projection on the selected axis. Possible choices are (see Figure 54 , page 128): • None • XZ • YZ • XZ & YZ
Grid & Axes	Turns on a grid for each dimension (see Figure 54 , page 128).
Line Width	Changes the thickness of the line. Maximum value is 10.
Fast Draw	Off (default) or On. When On, switches the display to a minimum number of display points when changing position or zooming the display. Resumes the previous Plot Style when done.
Page Buttons	
Freeze/Unfreeze	Toggles on and off the updating of the display window.
Save	Opens a standard Windows Save As dialog box to save the current profile as a graphic file (bmp, png, gif, jpg, or tiff format).
Print	Starts the Windows Print Manager to select an output printer. The full frame of the display is printed. The actual data frame depends on when the printing is initiated.
Default	Resets all options to their default values.
Help	Opens a Help screen describing mouse functionality within the 3D Display.

14.2 Mouse/Keyboard control

Using a combination of keyboard keys and the mouse, the user can manually change the size and the viewing characteristics of the

display. You can also see the pop-up help window by clicking [Help](#) on this page.

To Resize the Display Window:

1. Move the mouse to the border of the 3D Display Window.
2. Press the left mouse button, and drag the window until it is resized as desired.
3. Release the mouse button.

To Move the Display Window

1. Move the mouse to the Title Bar of the 3D Display Window.
2. Press the left mouse button, and drag the window to the desired location.
3. Release the mouse button.

To Zoom the 3D Image

1. Hold down the <Alt> key and the left mouse button.
2. Drag the mouse down to Zoom In (enlarge) the 3D image.
3. Drag the mouse up to Zoom Out (reduce) the 3D image.

An alternative to steps 2 and 3 is to use the mouse wheel: Scroll up to Zoom Out (reduce) and Scroll down to Zoom In (enlarge).

To Move the 3D Image within the Window (panning):

1. Hold down the <Shift> key and the left mouse button.
2. Drag the mouse left or right to move the 3D image along the X-Axis.

3. Drag the mouse up or down to move the 3D image along the Y-Axis.

To Rotate the 3D Image Around an Axis:

1. Hold down the <Ctrl> key and the left mouse button.
2. Drag the mouse to the right for a counter-clockwise rotation (around the Y-Axis).
3. Drag the mouse to the left for a clockwise rotation (around the Y-Axis).
4. Drag the mouse up for a “front-to-back” rotation (around the X-Axis).
5. Drag the mouse down for a “back-to-front” rotation (around the X-Axis).

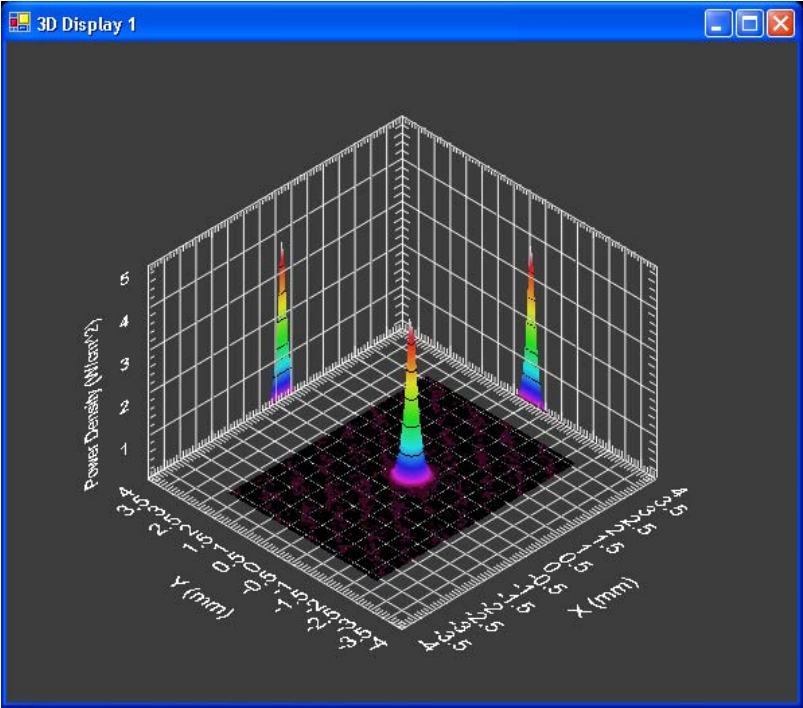


Figure 54: 3D with Grid, YZ Projection, and Surface Contour selected

15 Video Data Control

The Video Data Control page lets you store/play recorded camera output frames.

In recorder mode, the last specified number of frames is kept in memory.

In playback mode, frames can be played continuously or one at a time, forward or in reverse between frames in memory.

1. If the Video Data Control page is not present, click **Add** and click **Video Data Control** to add the page to the Control Panel form.

The page opens with default selections as shown in [Figure 55](#), page 129.

Refer to [Table 10](#), page 131 for an explanation.

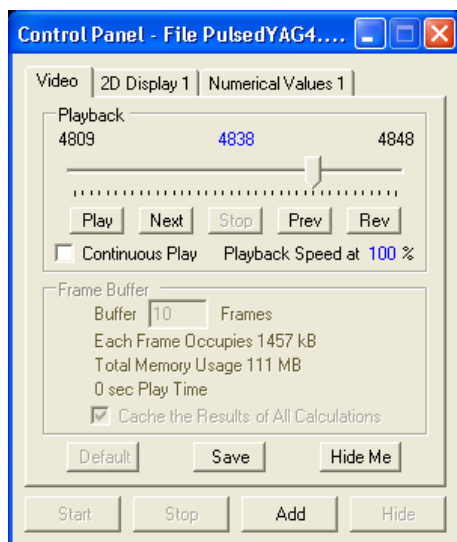


Figure 55: Video Data Control page

2. If a camera is attached when the page is added, recording begins automatically and continues until either **Stop** button is clicked.
3. To save the last group of frames:
 - a. Click a **Stop** button.
 - b. Click **Save**.
 - c. Accept the current file location or navigate to another and save the frames in memory as an *.00r file.

Note: This is a default extension, do **not** change.
 - d. Default location is \Samples in the BeamStar program path.
4. To open a previously stored video file:
 - a. In the menu bar, select **Source > Open > File**.
 - b. Navigate to the location and select the file.

BeamStar opens the file with the default displays ([Figure 11](#), page 47).

Table 10: Video Data Control options

Option	Explanation
Playback	
Slide and Pointer	Numbers indicates the first, stopped/Play (blue font), and last Buffer Frame, respectively. When not recording, the slide Pointer can be manually moved to one of the captured frames. Each stop is one frame of the number of Buffer Frames. When in Stop mode (recording or playback), clicking on the blue number opens a field for selecting any frame within the available range.
Play	Enabled when recording/playing is stopped. Displays the frames in memory from the first frame to the last frame. If Continuous Play is selected, Play will loop back to the first frame and continue.
Next	Enabled when recording/playing is stopped. Next plays the next frame each time the button is clicked until the last frame is played. If Continuous Play is selected, Next steps forward to the first frame.
Stop	Stops the display of the frames held in memory during a display that began by the Continuous Play, Play, or Rev buttons.
Prev	Enabled when recording/playing is stopped. Prev plays the previous frame each time the button is clicked, until the first frame is played. If Continuous Play is selected, Prev loops back to the last frame.
Rev	Enabled when recording/playing is stopped. Displays the frames in memory from the last frame to the first frame. If Continuous Play is selected, Rev loops back to the last frame and continues.
Continuous Play	Enables Play, Next, Prev, and Rev.
Playback Speed at	Default=100%. Rate at which the Play and Rev continuously play back frames in memory.

Option	Explanation
Frame Buffer	
Buffer Frames	Default=10. Last number of frames kept in memory. Number of Slide stops is equal to this number.
Each Frame Occupies	Read only to show memory required per frame.
Total Memory Usage	
Sec Play Time	Time displayed is (Number of Frames Stored) / (Camera Frame Rate at time of Recording).
Page Buttons	
Default	Enabled when a camera is attached. Resets Playback Speed and Buffer Frames to default values.
Save	After recording with a camera, saves the Buffer Frames to a location and name you specify. Allows saving a video file to another location and/or name.
Hide Me	Closes the page. Video playback and recording continues if previously started.
Control Buttons	
Start	Starts the camera and the recording of frames.
Stop	Stops the camera and the recording of frames. Last Buffer Frames number of frames is kept in computer memory, and can be played back and saved.

16 Region of Interest

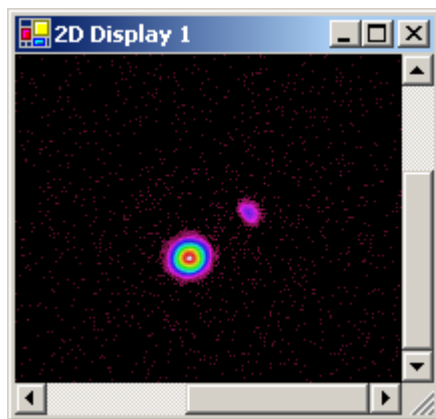
Region of Interest (ROI) lets you select a definable rectangular portion of the camera display for numerical analysis.

16.1 Need for Region of Interest

BeamStar algorithms and displays assume that all the pixels of the camera contain information vital for accurate measurement of the laser beam. This is correct in most cases, but occasionally it is necessary to perform calculations on a reduced set of data.

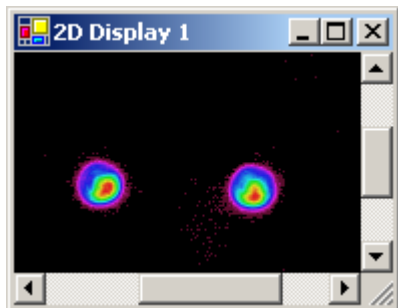
Example 1: Peripheral Noise or Ghost Image

Due to the Optical Setup of the experiment, a ghost image of the laser spot may be seen on the camera (see following figure). Including the ghost image will adversely affect the measurements.



Example 2: Multiple Spots

For a source that has multiple spots (see following figure), it may be necessary to measure each spot individually.



In order to perform correct measurement and analysis, BeamStar provides an easy-to-use Region of Interest (ROI) feature.

16.2 Using Region of Interest

16.2.1 Activation from Icon or Add Panel

To activate Region of Interest:

Use one of the following two methods:

- In the toolbar, click the icon .
- Select **Region of Interest** from the **Add Panel**.

A Region of Interest Tab Page is added to the **Control** Panel, and the Region of Interest is shown on the 2D Display as a yellow square.

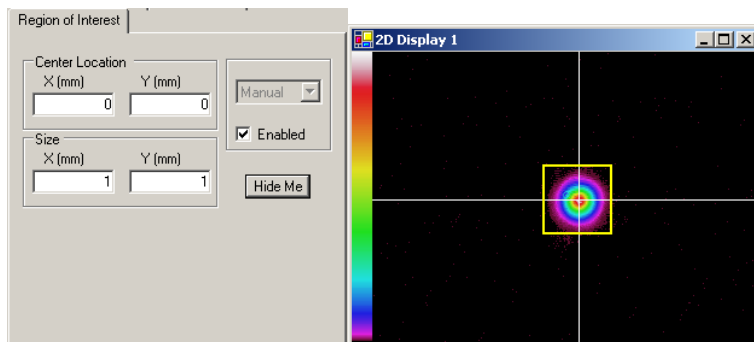


Figure 56: Region of Interest - control tab and example of 2D Display

16.2.2 Changing parameters from Control Tab or 2D Display

When the Region of Interest is started, it defaults to being centered in the camera with a size of 1x1 mm. Also, it starts in the Enabled state (all measurements are performed on data within the Region of Interest only).

To resize the Region of Interest:

Use one of the following two methods:

- In the Control Panel, change the **Size** controls as desired.
- Within the 2D Display do as follows:
 - a. Move the mouse to the border of the Region of Interest and press the mouse button.
 - b. Drag the mouse until the Region of Interest is resized as desired.
 - c. Release mouse button.

To move the Region of Interest:

Use one of the following two methods:

- In the Control Panel, change the **Center Location** as desired.
- Within the 2D Display:
 - a. Move the mouse into the Region of Interest and press the mouse button.
 - b. Drag the Region of Interest to the desired location.
 - c. Release the mouse button.

To perform measurements based on all pixels of the camera:

Use one of the following two methods:

- In the Control Panel, clear **Enable**.
This turns off the Region of Interest until it is clicked again.
- Click the **Hide Me** control. This removes the Region of Interest from the application.

16.2.3 Effect on 2D Display, Profiles, and Numeric Results

Enabling the Region of Interest causes the following effects:

- The Horizontal Scale of Profiles, 1D Gaussian Fit, and 1D Top Hat fit are limited to the Region of Interest.
- All measurements of all displays are based on pixels with the Region of Interest only.

The 3D Graph, however, is not affected.

In the following two figures, notice the little bump caused by a ghost image when the Region of Interest is not enabled, whereas the ghost image bump is eliminated when the Region of Interest is enabled.

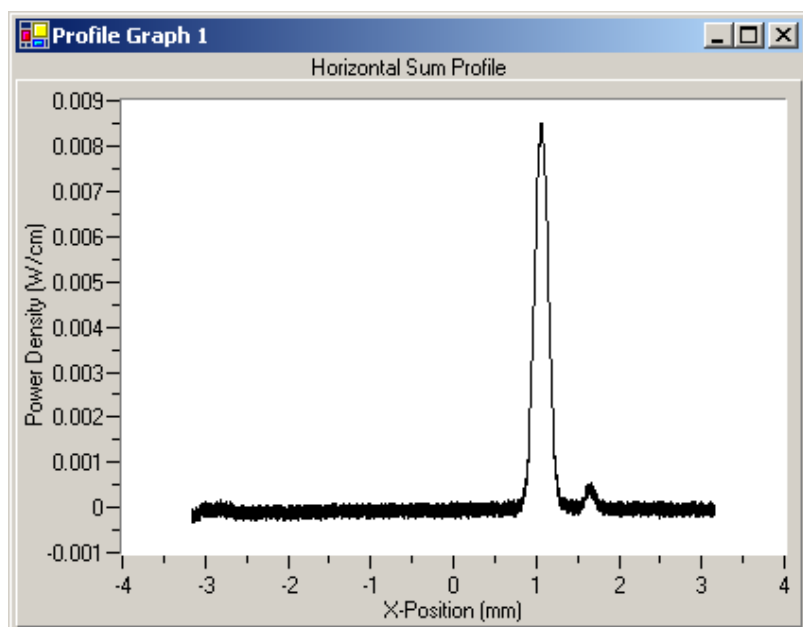


Figure 57: Sum profile on X-axis with ROI not enabled

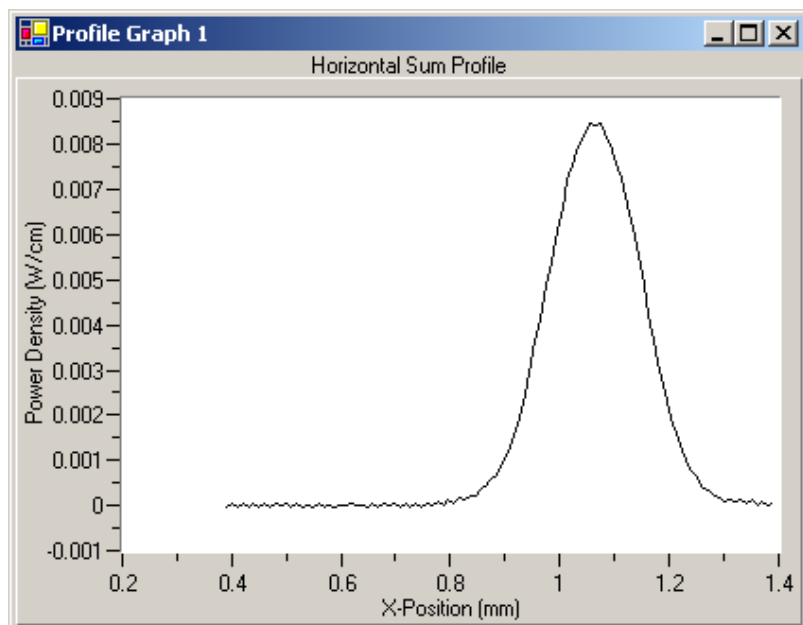


Figure 58: Sum Profile on X-axis with ROI enabled

In the following two figures, notice the elongation of the 4σ Beam Marker and the effect on the measured beam width due to a ghost image when the Region of Interest is not enabled, whereas the 4σ beam marker is circular and the measured result is much smaller when the Region of Interest is enabled.

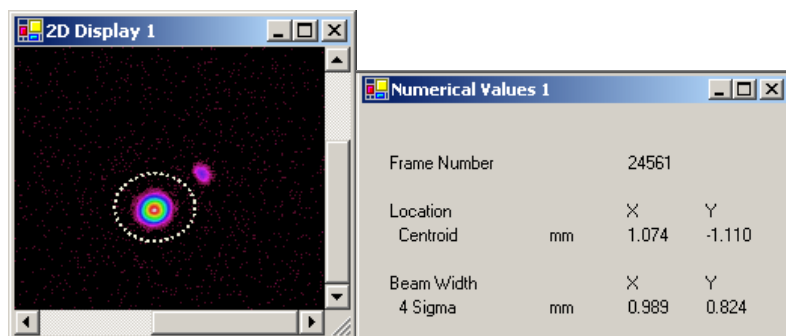


Figure 59: Region of Interest not enabled

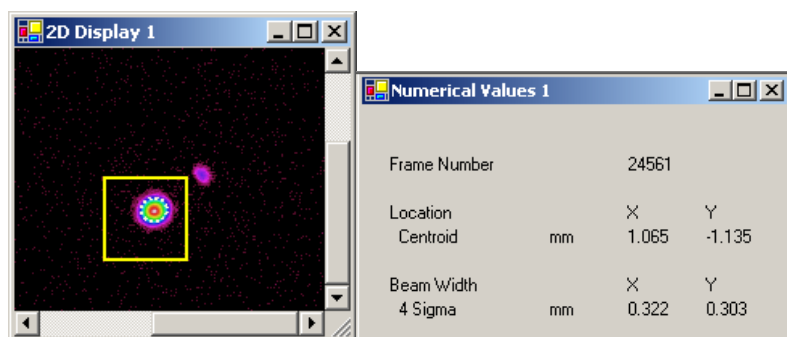


Figure 60: Region of Interest enabled

17 Major/Minor Axes

17.1 Reference Axes

By default, BeamStar software assumes that the laser spot is aligned with the vertical and horizontal axes (X,Y) of the camera. That is to say, there are vertical and horizontal lines that can cut through the beam at its largest width on either axis (X,Y).

This assumption about alignment is not always true. Sometimes the spot of the laser is rotated at an angle to the XY axes of the camera. In such a case, the beam widths are more correctly measured along the Angle of Rotation.

The orthogonal axes that cut through the laser beam's centroid along the Angle of Rotation are known as the Major and Minor axes. The Major axis is defined as the axis along which lies the longer Beam Width. The Minor axis is defined as the axis along which lies the shorter Beam Width.

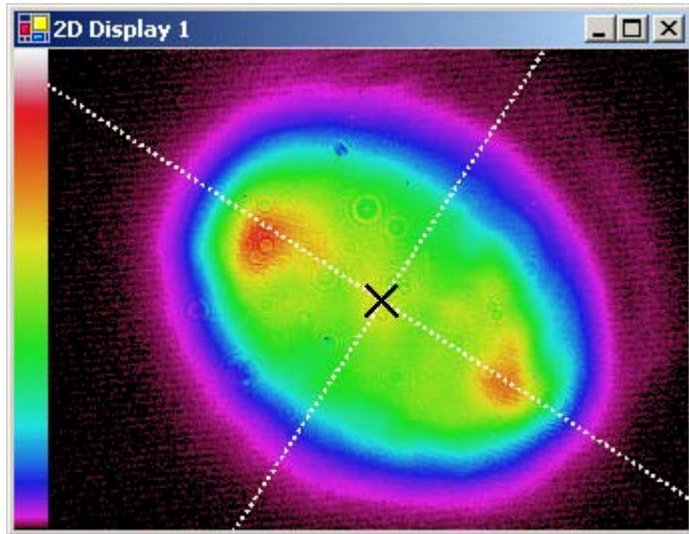


Figure 61: Major and Minor lines drawn through the centroid of a rotated laser beam

Working and making measurements with the horizontal and vertical axes is known as the Default XY mode. Working and making measurements along the Major and Minor axes is known as the Beam Axis mode.

17.2 Effect on Displays and Calculations

The following displays can be set to provide results based on Major and Minor axes.

17.2.1 2D Display with Major/Minor Marker enabled

- Orthogonal lines will be drawn through the centroid along the Major and Minor axes.
- If a 4σ beam-width is selected, the ellipse encircling the 4σ beam width will be centered at the centroid and based on the lengths of the 4σ beam widths of the Major and Minor axes.

17.2.2 Numeric Results Aligned to Beam Axis

- All beam width measurements will be based on Major and Minor axes.
- An Azimuth Angle can be selected.
- A 2D Gaussian fit will be based on Major/Minor axes.

17.2.3 Profiles, 1D Gaussian, 1D Top Hat

- Display of the profile and fits can be aligned to the Major or Minor lines.
- Line profiles will be aligned to the centroid.

17.3 Axis Alignment Control

The Axis Alignment Control is provided for configuring the entire application to Default XY or Beam Axis measurement.

If desired, individual displays can be configured to Major/Minor or X/Y axes (for example, the 2D Display or the 1D Gaussian fit).

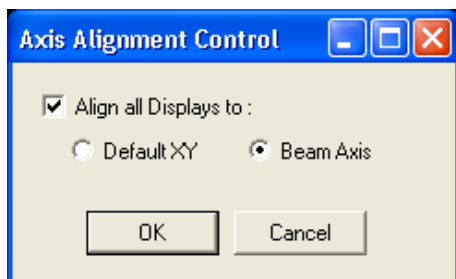
17.3.1 Setting all BeamStar Displays to one set of Axes

To align all displays to one set of axes:

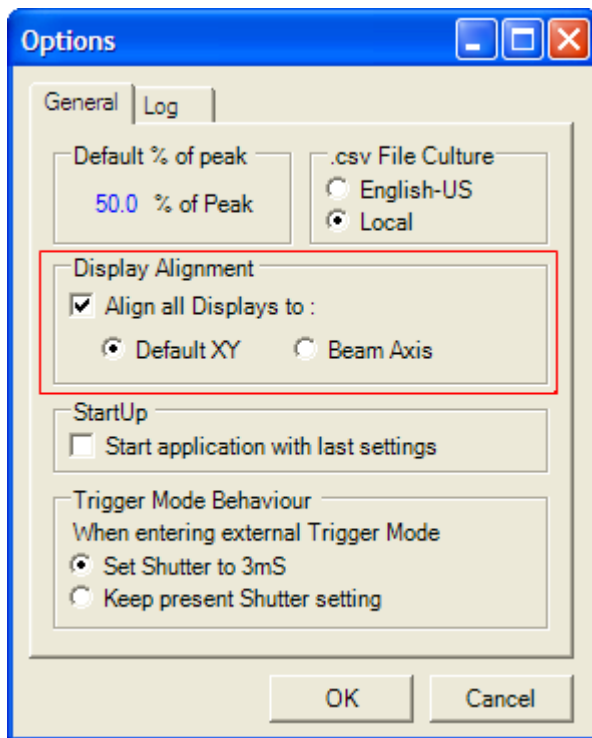
1. Use one of the following two methods:

- In the toolbar, click the icon .

The Axis Alignment Control dialog box opens.



- From the Menu bar, select **Tools > Options**.



2. Select **Default XY** or **Beam Axis**, as desired.
3. Verify that **Align all Displays to** is checked.
If it is not checked, the axis change will not occur.
4. Click **OK** to make the axis change.

17.3.2 Effect of Align All Displays on Control Tabs

If **Align all Displays to** is in effect, certain controls in the various displays' Control Tabs will not be fully functional.

When **Align all Displays to** is set to **Default XY**:

- 2D Display:
 - **Major/Minor Marker** is grayed out.

- Profiles, 1D Gaussian Fit, 1D Top Hat Fit:
 - **Major and Minor Axes** cannot be selected.
 - All **Align To** controls are available in **Line Profiles**.
- Numeric Results:
 - **AlignTo** will be set to **DefaultXY** and cannot be changed.
 - **Azimuth Angle** cannot be selected.

When **Align all Displays to** is set to **Beam Axis**:

- 2D Display:
 - **XY Cursors Marker** is grayed out.
 - **Align XY Cursors** is grayed out.
- Profiles, 1D Gaussian Fit, 1D Top Hat Fit:
 - **X and Y Axes** cannot be selected.
 - **Line Profiles** will be aligned to **Centroid**.
- Numeric Results:
 - **AlignTo** will be set to **Beam Axis** and cannot be changed.

18 M² (M Squared)

This section explains the theory of operation for M² (see following, sentence) and describes the Ophir solution. M² is a quantity that measures how close the beam parameter product of the laser in question is to the diffraction limit of a perfect Gaussian beam.

For an explanation of technical terms used in this section, see [Glossary](#), page 159.

18.1 Theory of Operation

18.1.1 What is M²

Two important characteristics that are not measured by standard Beam Profiling packages are the Waist Diameter of a laser beam and its Divergence Angle. In layman's terms, these are "how small is the laser beam when focused" and "at what rate does it spread out afterwards".

For any wavelength there is a theoretical minimum to the product of the Waist Diameter and Divergence Angle that must be greater than $((4/\pi) * \text{wavelength})$. A perfect Gaussian beam (also known as a TEM₀₀ beam) approaches this limit.

M² is the quantity that measures how close the beam parameter product of the laser in question is to the diffraction limit of a perfect Gaussian beam. ISO 11146 is the internationally recognized standard that defines M² measurement.

18.1.2 M² Equation

M² is given by the equation

$$M^2 = \frac{\pi}{\lambda} \cdot \frac{d_{\sigma 0} \Theta_{\sigma}}{4}$$

where:

λ is Wavelength of the laser beam.

Θ_{σ} is Divergence Angle.

$d_{\sigma 0}$ is Waist Diameter.



Note: Although we use the simpler notation of a radially symmetric beam, calculation of M² and all of its components is made for X and Y individually. Any mention of Waist Diameter should be understood as reference to Waist Width X and Waist Width Y.

As can be seen in the above equation, different combinations of Waist Diameter and Divergence Angle can lead to the same results for M². This formula implies that for lasers of the same wavelength with different Waist Diameters, the Divergence Angle must be different in order to obtain the same value for M².

Of the three variables that go into the equation to calculate M², only the wavelength of the laser under test is known at the start of the measurement process. Divergence Angle and Waist Diameter must be determined by the M² measurement process before they can be used, in turn, to calculate M².

18.1.3 Beam Width and Centroid

At this point a full definition of Beam Width is in order. The BeamStar software supports several definitions of Beam Width. However, for purposes of determining M² or any component thereof, ISO 11146 requires use of the 4 σ Beam Width. This is defined mathematically as being four times the square root of the second moment of the power distribution of the laser beam. It is given by the equations

$$d_{\sigma x}(z) = 4\sigma_x(z) \quad d_{\sigma y}(z) = 4\sigma_y(z)$$

σ (Sigma) is given by the equations

$$\sigma_x^2(z) = \frac{\iint (x - \bar{x})^2 E(x, y, z) dx dy}{\iint E(x, y, z) dx dy} \quad \sigma_y^2(z) = \frac{\iint (y - \bar{y})^2 E(x, y, z) dx dy}{\iint E(x, y, z) dx dy}$$

where $(x - \bar{x})$ and $(y - \bar{y})$ are the distances to the centroid $(\bar{x}, \bar{y})$

The centroid is given by the equations

$$\bar{x} = \frac{\iint x E(x, y, z) dx dy}{\iint E(x, y, z) dx dy} \quad \bar{y} = \frac{\iint y E(x, y, z) dx dy}{\iint E(x, y, z) dx dy}$$

where $E(x, y, z)$ is the power distribution function of the laser beam.

18.1.4 Divergence Angle

The Divergence Angle is the angle of the cone that describes the increase of a laser beam's width as it travels through space. It is given by the equation

$$\Theta_\sigma = \frac{d_\sigma}{f}$$

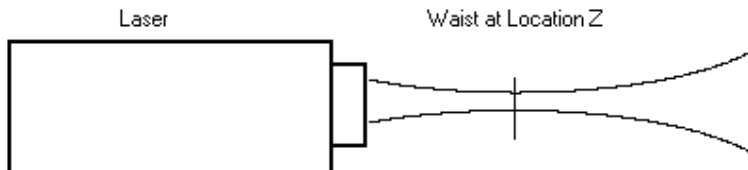
where

d_σ is Beam Width as measured one focal length away from the Rear Principal Plane of the Focusing Element.

f is Focal Length of the Focusing Element.

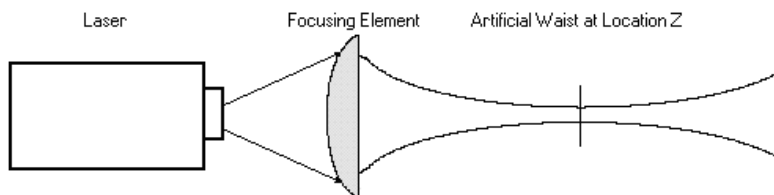
18.1.5 Waist Diameter

Waist Diameter is the laser beam's minimum size. Waist Diameter Location is the Z-Position at which the Waist Diameter was measured.



Measuring the true Waist Diameter of a laser beam is very often a difficult (if not impossible) task. The beam may not naturally converge outside the laser cavity. Even if it does converge, the location might be outside of the physical space allocated for working with the laser under test.

The approved alternative is to work with an artificial waist. This entails passing the laser beam through a Focusing Element. ISO 11146 provides details on how to calculate the true Waist Diameter based on measurements made in the area of the Artificial Waist.



18.1.6 Practical Limitations

In theory M² should be a straightforward and simple measurement:

- The wavelength of the laser is known.
- Measure the Beam Width at the Focal Length to get the Divergence Angle.

- Find the Beam Waist by moving the BeamStar along the laser beam's optical path until the minimum is found.
- Apply the M² equation to the above.

In practice, this is not realistic. As mentioned above, the Beam Waist may be inaccessible for measurement. Also, there are many potentially sources of measurement error:

- Inaccurate measurement of Z-Position
- Surface Aberrations on the Focusing Element
- Inaccuracy of the measurement device itself
- Calculations based on incorrect Focal Length

Therefore, all M² systems base their calculations on a larger set of measurements:

- Each measurement is actually an average of at least five measurements at that Z-Position.
- Move the Camera to the Z-Position where the smallest beam width can be measured.
- Take at least five measurements close to the minimum measured (within a distance of one Rayleigh Range).
- Take at least five measurements in the far field (at least two Rayleigh Ranges away from the minimum).

Based on the measured data, M² can be calculated as follows:

- Use curve-fitting techniques to determine the Artificial Waist and the Divergence Angle.
- Determine the true Waist Diameter.
- Calculate M².

Using the above technique, M² accuracy is expected to be $\pm 10\%$.

18.1.7 Rayleigh Range

As mentioned above, several measurements must be made close to the minimum measured and several must be made far away. The Rayleigh Range (or Rayleigh Length) is used as the definition of proximity to or distance from the Beam Waist.

The Rayleigh Range is defined as the distance from the Beam Waist along the Z-Axis at which the beam width is a factor of $\sqrt{2}$ greater than the width of the Beam Waist (see following equation).

$$d_R = \sqrt{2} * d_{\sigma 0}$$

Measurements taken within one Rayleigh Length of the waist are considered in close proximity to the Beam Waist.

Far Field is defined as a Z-Axis distance much greater than the Rayleigh Range away from the Beam Waist. For M² purposes, any location more than two Rayleigh Ranges from the Beam Waist is considered in the Far Field.

18.2 Ophir Solution

18.2.1 Overview

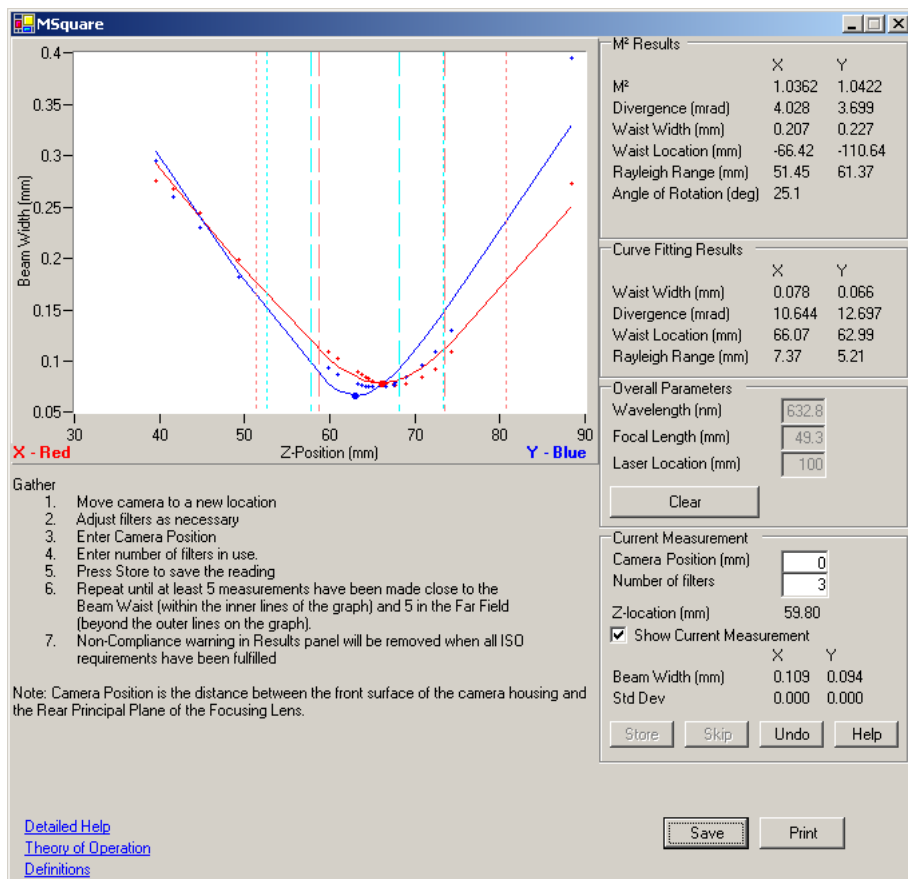
Different users will have different expectations from an M² measurement system. Manufacturers of large multi-mode YAG lasers will need a different optical setup than makers of small HeNe lasers. One user may require greater accuracy at a higher price than another user who will be satisfied with a cheaper and less accurate system.

Ophir provides a software platform that can be used to build an M² measurement system tailor-made for a user's specific needs. This software backbone is the same for everyone. The customization is provided by the user.

18.2.2 The M² Display

The M² Display (see example in the following figure) is comprised of the following components:

- Measurement Graph
- M² Results panel
- Curve Fitting Results panel
- Overall Parameters Setup panel
- Current Measurement panel
- Stage Sensitive Help

Figure 62: M² Display Panel

Measurement Graph

The Measurement Graph (see example in following figure) displays the X and Y Beam Widths vs. Z-Position. Markers are shown where the measurements were actually made. The results of the Curve Fitting algorithm are displayed as well. X is displayed in red and Y in blue. A large dot marks the Artificial Waist Location.

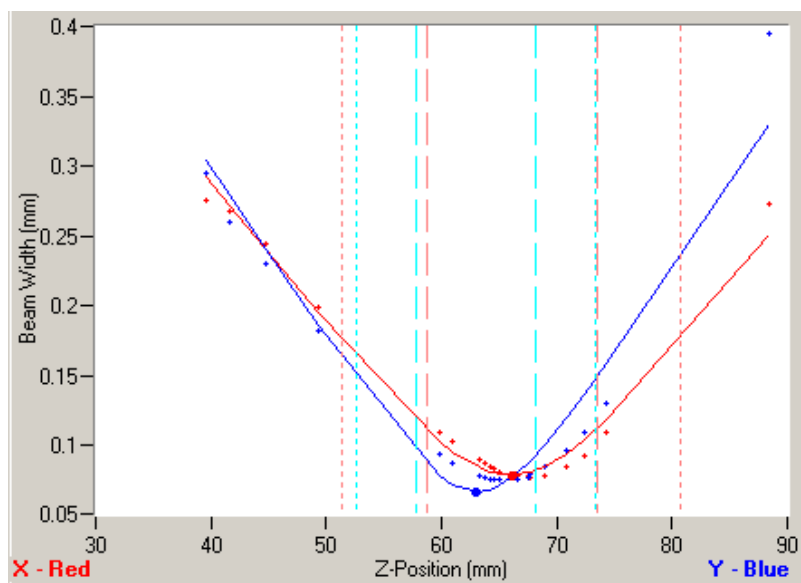


Figure 63: Measurement Graph - X and Y Beam Widths vs. Z-Position

This graph includes vertical Rayleigh Range markers as well. The markers closest to the Waists are one Rayleigh Range away from the Waists. At least five measurements must be within these markers in order to be compliant with ISO 11146. The markers that are further away are two Rayleigh Ranges away from the Beam Waists. At least five measurements must be beyond these markers (Far Field measurements) in order to be compliant with ISO 11146.

M² Results Panel

The Results Panel (see example in following figure) contains the final M² results. These are calculated based on the curve fitting applied to the measurements made on the laser beam in the area of the Artificial Waist.

M ² Results		
	X	Y
M ²	1.0362	1.0422
Divergence (mrad)	4.028	3.699
Waist Width (mm)	0.207	0.227
Waist Location (mm)	-66.42	-110.64
Rayleigh Range (mm)	51.45	61.37
Angle of Rotation (deg)	25.1	

If minimum ISO 11146 measurement requirements have not been met, a non-compliance warning will be displayed in this panel.

Curve Fitting Results panel

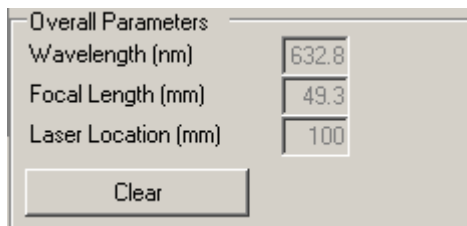
The Curve Fitting Results (see example in following figure) are the results of applying curve-fitting techniques to the beam width measurements made after passing through the focusing lens. These are the Artificial Waist Widths and associated factors.

Curve Fitting Results		
	X	Y
Waist Width (mm)	0.078	0.066
Divergence (mrad)	10.644	12.697
Waist Location (mm)	66.07	62.99
Rayleigh Range (mm)	7.37	5.21

BeamStar will apply a curve-fitting algorithm as soon as enough measurements have been made to do so. However results will not be ISO compliant until the minimum number of measurements that ISO 11146 requires has been made.

Overall Parameters Setup panel

The Overall Parameters (see example in following figure) are the global parameters that define the laser and setup of the test equipment. These must be set before the M² measurement process can begin.



Overall Parameters	
Wavelength (nm)	632.8
Focal Length (mm)	49.3
Laser Location (mm)	100
Clear	

The user sets up the following overall measurement parameters:

- **Wavelength:** Wavelength (in nanometers) of the laser being measured.
- **Focal Length:** Distance from the Rear Principal Plane of the Focusing Lens to the Focal Point.

This value is dependent on the nominal Focal Length as given by the manufacturer and the wavelength being measured. For example, a lens with a 400 mm Focal Length calibrated at 589.3 nm actually has a Focal Length of about 402 mm for an HeNe laser whose wavelength is 632.8 nm.

- **Laser Location:** Distance between the front of the laser housing and the Front Principal Plane of the Focusing Lens.

All beam width measurements are made in the area of the Artificial Waist. However, M² is based on the actual waist. The distance between the Reference Plane (usually the front of the laser) and the Front Principal Plane of the Focusing Element is used as part of the formula to translate from Artificial Waist to the actual Beam Waist.

- **Start Process:** Registers the Global Parameters and enables the M² measurement process. After being clicked, it becomes the **Clear** button.
- **Clear:** This clears all the Global Parameters and restarts the M² measurement process.

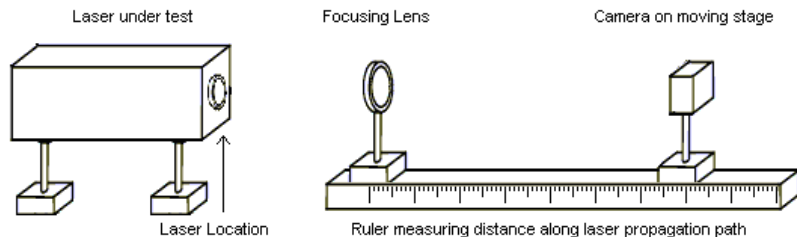


Figure 64: Typical setup for measuring M² of a laser

Current Measurement panel

In the Current Measurement section (see example in the following figure) the user sets the parameters that are specific to the current measurement.

The screenshot shows the 'Current Measurement' panel with the following settings:

Camera Position (mm)	0	
Number of filters	3	
Z-location (mm)	59.80	
☒ Show Current Measurement		
	X	Y
Beam Width (mm)	0.109	0.094
Std Dev	0.000	0.000

At the bottom of the panel are four buttons: Store, Skip, Undo, and Help.

These parameters affect the Z-Axis location measurement. Accuracy is very important. In fact, Z-Position inaccuracy is one of the greatest sources of error in M² measurement.

Z-Position must be measured from the Rear Principal Plane of the Focusing Lens, and not necessarily from the back of the lens.

- **Camera Position:** The distance between the front surface of the camera housing and the Rear Principal Plane of the Focusing Lens.
- **Number of Filters:** The number of filters being used to make this measurement.

This value affects the Optical Distance between the Lens and the camera. Without going into details of Index of Refraction, as the amount of glass between the Focusing Lens and the Camera increases, the closer the camera seems to be to the lens.

- **Z-Location:** The distance between the Focusing Lens and the CCD of the camera.

This value equals Camera Position + Internal Distance between CCD and front of BeamStar camera – (1/3 * Number of Filters).

- **Show Current Measurement.** When checked, the BeamStar is prepared to make another Beam Width measurement.
- **Beam Width** (or Divergence Angle) presently measured.
- **Store Button:** Saves this measurement and recalculates results based on a new curve fitting.

This button is disabled until the Camera Position and Number of Filters parameters are updated and at least five measurements have been made and averaged together (ISO requirement).

- **Skip Button:** Used to skip the preliminary stages of advanced M² measurement. Most users should skip these stages.
- **Undo:** Occasionally there will be an outlier measurement (a measurement so obviously wrong that it should be discarded).

To undo, first click the measurement in the graph. This disables the **Show Current Measurement** check box and displays the questionable measurement. Clicking **Undo** removes it, and updates the graph as well.

The **Undo** button can also be used to undo the last result when performing preliminary stages of advanced M² measurement.

Stage Sensitive Help panel

The Stage Sensitive Help panel (see the example in the following figure) contains brief instructions on how to continue the M² measurement process. Contents of this panel are sensitive to the stage of measurement that the user has reached.

This pane also contains links to various detailed explanations of M² measurement.

Gather

1. Move camera to a new location
2. Adjust filters as necessary
3. Enter Camera Position
4. Enter number of filters in use.
5. Press Store to save the reading
6. Repeat until at least 5 measurements have been made close to the Beam Waist (within the inner lines of the graph) and 5 in the Far Field (beyond the outer lines on the graph).
7. Non-Compliance warning in Results panel will be removed when all ISO requirements have been fulfilled

Note: Camera Position is the distance between the front surface of the camera housing and the Rear Principal Plane of the Focusing Lens.

[Detailed Help](#)

[Theory of Operation](#)

[Definitions](#)

18.2.3 Stages of Measurement

The following are the stages of the Ophir M² Measurement:

1. Setup of Overall Parameters

This step must be performed before the M² Measurement Process can begin.

2. First Approximations



Note: This step is for advanced users only. Most users should skip straight to the Gather Data step.

These are optional stages that allow the user to make a first-order approximation of the following measurements:

- Divergence Angle
- Beam Waist of X and Y

- Rayleigh Range of X and Y

3. Gathering Data

This is the main measurement stage. Although ISO 11146 demands at least ten measurements with half of them being close to the waist and the other half in the Far Field, BeamStar will display results as soon as enough measurements have been made to apply curve fitting techniques.

These results should be seen as a rough estimate of M² and as an indicator where to perform more measurements.

A disclaimer will be displayed stating Non-ISO compliance until enough measurements have been gathered to meet the minimum ISO 11146 requirements.

18.2.4 Attenuating the Laser Beam

In the course of an M² measurement, the power density on the camera in use will change drastically:

- When the camera is close to the waist, the spot will be small and the power density relatively high. This will demand increased attenuation (by a combination of filters or beam splitters) and keeping exposure and gain low, but high enough to get a good signal. Failure to do so can lead to erroneous measurements due to the CCD being saturated. It can also cause damage to the CCD.
- In the Far Field, the spot size will be larger. This can lead to a weak signal on the detector. In such circumstances, the exposure must be brought up, and the attenuation reduced.

If the measurement is fluctuating at a given location, this may be due to noise. In such a case, use the averaging feature of the Noise Control Panel (refer to page 30).

18.3 Glossary

Below is an alphabetic list of technical terms used in this section.

Artificial Waist

Laser beam's minimum size when measured after being passed through a Focusing Element.

Back Focal Length

Distance from the back edge of a Focusing Element to its Focal Point. This is usually not the same distance as the Focal Length. The manufacturer that supplies the Focusing Element usually lists both distances. The Focal Length is the distance that is necessary for calculations. However, the Back Focal Length is much easier to physically measure.

Beam Divergence

Tendency of a laser beam to expand in diameter as it moves away from its source.

Beam Width

Also known as 4σ beam width. This is defined mathematically as being four times the square root of the second moment of the power distribution of the laser beam.

Camera Position

The location of the camera along the Optical Path of the laser beam after it has passed through the Focusing Lens. This is the distance between the Rear Principal Plane of the Focusing Lens and the front surface of the camera casing. See also Z-Location.

Centroid

Also called the Center of Gravity. This is the first moment of the power distribution of a laser beam.

Divergence Angle

Angle of the cone that describes the increase of a laser beam's width as it travels through space.

Far Field

When the Z-Axis distance is much greater than one Rayleigh Range away from the Beam Waist.

Focal Length

The distance from the Rear Principal Plane of a Focusing Element to the Focal Point (the point at which parallel rays of light passing through the lens should converge).

Focusing Lens

The optical component (usually a simple lens; in some cases it may be a complex Optical Assembly) used to focus parallel rays of light, causing them to converge at a determined point. When this consists of more than a simple lens, it is more correctly referred to as Focusing Element.

Four Sigma Beam Width

See Beam Width.

Optical Distance

The actual length of a light path in a substance divided by the refractive index of that substance. Example: Glass has a Refractive Index of about 1.5. Air has a Refractive Index of about 1. The optical distance of 3 mm of glass is 2 mm ($3 \text{ mm} / 1.5 = 2 \text{ mm}$).

Optical Path

The path of a laser beam as it travels through space. This is sometimes referred to as Propagation Path or Z-Axis.

Rayleigh Range (also called Rayleigh Length)

The distance from the Beam Waist along the Z-Axis at which the beam width is a factor of $\sqrt{2}$ greater than the width of the Beam Waist.

Rear Principal Plane

The plane from which the Focal Length of the Focusing Element is measured. This is usually not the rear edge of the Focusing Element. The manufacturer that supplies the Focusing Element usually lists both distances. The Focal Length is the distance necessary for calculation of the Z-Axis position. However, the Back Focal Length is much easier to physically measure. Therefore, simply measure from the rear edge of the Focusing Element, add the difference between Back Focal Length and Focal Length, and you have the distance from the Rear Principal Plane. See also Back Focal Length.

Times Diffraction Limit Factor (M²)

Measures how close a laser beam is to a perfect Gaussian beam. This is equal to unity (1) for a theoretically perfect Gaussian beam and has a value of greater than 1 for any real laser beam.

Waist Diameter

The laser beam's minimum size.

Waist Diameter Location

The position along the Z-Axis at which the Waist Diameter was measured.

Z-Axis

See Optical Path.

Z-Location

The location on the Z-Axis of the CCD array of the BeamStar camera. This is determined by the Camera Location, the distance between the Front surface of the camera and the CCD array, and the number of filters in use.

19 Automation

Ophir provides a sophisticated interface to allow other applications to access BeamStar measurements and to integrate them into their client applications.

This interface makes use of .NET technology.

BeamStar installation creates a directory named “Automation Examples” as a subdirectory of the BeamStar application directory. It contains the following:

- Sample client application in VB.NET
- Sample client application in VB6
- Sample client application in LabVIEW 7.0
- Automation Guide. This is a Word document fully describing use of all objects of the BeamStar Automation Interface

20 Optical Accessories

Optical Accessories extend the measurement capabilities of the BeamStar cameras in three ways:

- Attenuate laser beam power to within the operational range of the BeamStar cameras.
- Extend the size and resolution limitations of the cameras.
- Measure beyond the standard spectral range (350nm – 1100nm) of silicon based sensors.



Note: See our latest catalogue for the most up to date information on accessories and part numbers.

20.1 Transmission Filters (P/N SPZ08235, SPZ08234)

Transmission filters are screw-on ring filters that attenuate the amount of laser beam transmitted to the sensor.

One NG9 (red casing, P/N SPZ08234) and two NG10 (black casing, P/N SPZ08235) filters are provided with the BeamStar camera. Additional filters can be ordered.

The NG9 filter transmits between 5% and 20% of the laser beam, depending on its wavelength.

The NG10 filter transmits between 0.5% and 7% of the laser beam, depending on its wavelength.

Both filters are 1mm thick.



Figure 65: BeamStar Camera with one red and two black filters

20.2 Variable Attenuator (P/N SPZ17012)

NG9 filter of varying thickness (from 1.4 to 6.5mm). This allows the user to vary the transmission over four orders of magnitude without the need to add and remove filters from the camera.

This is actually two wedge-shaped filters in one housing. The wedge shape helps reduce interference effects on the BeamStar measurements.



Figure 66: BeamStar Camera with Variable Attenuator

20.3 Beam Splitters (P/N SPZ17015, SPZ17026)

45° wedge beam splitter. Each beam splitter reduces the intensity of the laser beam by approximately 20x1. Up to three beam splitters can be mounted, thereby reducing the laser spot's power by 8000x1.

The first beam splitter (P/N SPZ17015) is mounted directly on the camera. It can also be mounted on top of filters or the variable attenuator.

Additional beam splitters (P/N SPZ17026) can be mounted (at right angles) on the previously mounted beam splitters.

The spectral range of the beam splitters is 190nm to 2500nm.



Figure 67: BeamStar camera with two Beam Splitters mounted

20.4 4X Beam Reducer (P/N SPZ17017)

An imaging assembly that is mounted onto the BeamStar camera, the Beam Reducer images the laser beam as it appears at the plane 30cm in front of the reducer onto the CCD while at the same time reducing the size by a factor of four. This enables measurement of laser beams up to 24x18mm with the BeamStar FX50 camera.

The spectral range of the Beam Reducer is 360nm to 1100nm.

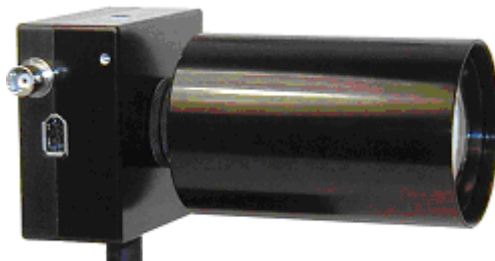


Figure 68: BeamStar Camera with 4X Beam Reducer

Beam reduction causes the power density to increase by a factor of 16. Therefore, Ophir provides special filters (P/N SPZ08240) and beam splitter (P/N SPZ17018) to be placed between the laser source and the Beam Reducer.

20.5 4X Beam Expander (P/N SPZ17022)

An imaging assembly that is mounted onto the BeamStar camera, the Beam Expander images the beam as it appears 8mm in front of the expander onto the CCD while at the same time enlarging it by a factor of four. This enables measurement of very small laser spots. Used with an FX 50, this gives an effective resolution of 2 or 3 microns. It is recommended for converging and diverging beams, but may have interference effects for very parallel beams.

The spectral range of the Beam Expander is 360nm to 1100nm.



Figure 69: BeamStar Camera with 4X Beam Expander

A fiber adapter bracket (P/N SPG01649) is available to ensure proper mounting and measurement of fiber adapters with the Beam Expander.

20.6 BeamStar UV Converters

BeamStar cameras are not sensitive to UV light. However, Ophir provides accessories that allow measurement of UV laser beams with standard BeamStar cameras.

The UV beam falls on a fluorescent plate and fluoresces in the visible spectrum range. The fluorescent plate is transparent to the

visible light but not to the UV therefore only the light which is converted from UV to visible is transmitted.

This technology converts the spectral range of the BeamStar cameras from 190nm to 350nm.

20.6.1 BeamStar U 4x reducing (P/N SPZ17024)

UV Converter that also acts as a 4X Beam Reducer



Figure 70: BeamStar with BeamStar U-V1 Converter/Reducer

A Beam Splitter (P/N SPZ17007) that can be mounted directly on the BeamStar U-V1 is also available.

20.6.2 BeamStar U 1X (P/N SPZ17023)

UV Converter with no reduction/expansion

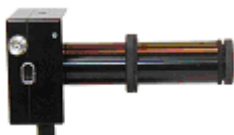


Figure 71: BeamStar with BeamStar U 1X Converter

If beam splitting is necessary, this can be done with the standard (P/N SPZ17015) Beam Splitter described above.

20.6.3 BeamStar UV Converter (P/N SPZ17019)

Special UV converter plate for use with the 4X Beam Expander (P/N SPZ17022).



Figure 72: UV Converter



Figure 73: BeamStar with UV Converter mounted on 4X Expander

20.7 355nm Filter (P/N SPZ08246)

The Spectral range of the BeamStar FX 50 and FX 33 series extends down to 350nm. Therefore, it should be possible to measure the third harmonic of YAG laser at 355nm.

However, most Q switched frequency multiplied YAG lasers, when set to 355nm, do not emit only 355nm but also some remnants of 532nm and 1064nm. Since the BeamStar FX cameras are much more sensitive to longer wavelengths than to shorter ones, it is virtually impossible to see the 355nm beam profile without it being swamped by the other wavelengths.

Ophir therefore offers a special filter which transmits most 355nm radiation, but almost completely blocks 532nm and 1064nm radiation. This filter can be mounted on top of the standard filters described above. It is distinguished by its green casing.

21 BA500



Figure 74: BA500 Industrial Laser Beam Analyzer

The BA500 (P/N SP186007, SP186008) is an integrated measurement system. It couples the beam profiling capabilities of the BeamStar with the power, energy, and temporal pulse shape measurement capabilities of Ophir's RP heads.

Full functionality of the BA500 is described in the BA500 User Manual that is included in the packing contents of the BA500.

This chapter describes how to configure the BeamStar application and camera parts of the BA500. It also lists and explains the use of [Optical Accessories](#), page 164 that are included in the BA500 assembly.

21.1 BeamStar Accessories in the BA500

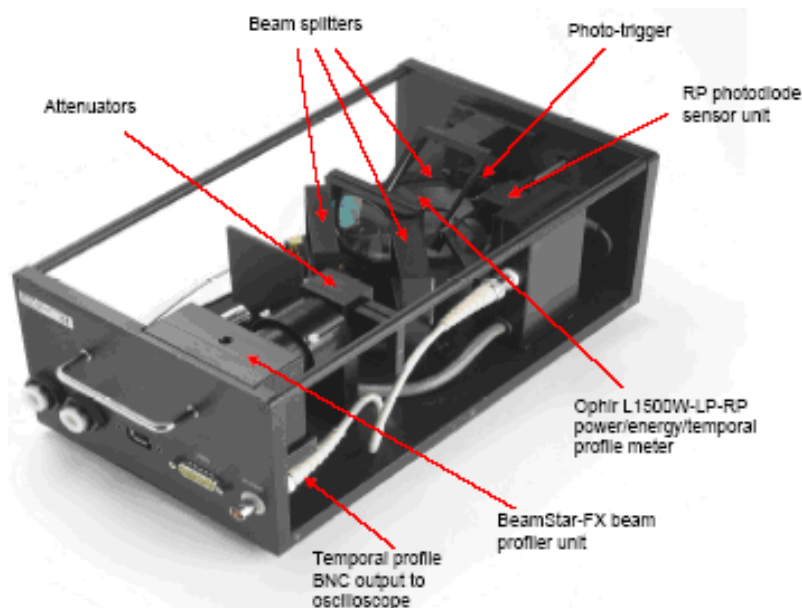


Figure 75: BA500 components

21.1.1 Cameras

Each BA500 comes equipped with either a standard a SP503U or with an FX50 (BC102) camera.

21.1.2 Beam Splitters

In order to measure high powered industrial lasers, the laser beam must be attenuated significantly. The BA500 assembly includes three Beam Splitters, thereby causing an 8000:1 reduction in laser power intensity.

21.1.3 Optical Photodiode Trigger

An Optical Photodiode Trigger (OPT) is included in the BA500 to enable syncing on pulsed lasers. See [Ophir Photodiode Trigger](#)

[\(OPT\)](#), page 26 for details on triggering measurements with the OPT.

21.1.4 Variable Attenuator

There is no access to the camera's aperture from outside the BA500. Therefore, to allow filter attenuation, the BA500 is equipped with a built-in Variable Attenuator (P/N SPZ17012).

An instruction label is attached under the adjustment rods of the Variable Attenuator explaining how to maximize or minimize attenuation.

21.1.5 Imaging Lenses

Industrial lasers may be as large as 10's of mm. In order to measure such large laser beams, the BA500 is equipped with imaging lenses (between the first two beam splitters in the picture above) that image the laser beam (as seen at the entrance window of the BA500) onto the CCD while reducing it in size by a factor of seven.

21.2 BA500 Setup for Beam Profiling

21.2.1 Physical Setup

The following precautions must be taken when using the BA500. Failure to do so will result in erroneous measurements and may cause permanent damage to some (or all) components in the BA500 assembly.

- Remove the final focusing lens of the laser under test so that the emerging beam is parallel.
- Make sure that there is at least 5½" (140mm) of clearance between the laser output and the table upon which the BA500 will be mounted.
- Connect a water source and set it to flow at a rate of at least 2½ liters per minute

21.2.2 BeamStar Setup

- Set the Optical Scaling Factor to Beam Enlarged, Times 7 (see [Optical Scale Factor](#), page 23).
- For CW or high frequency lasers, see [Internal Trigger \(CW Mode\)](#), page 32.
- To synch measurements on pulsed lasers, see [Ophir Photodiode Trigger](#), page 39.
- To save the camera configuration, see [Customizing the BeamStar Startup](#), page 50.



Note: If your laser has a polarized beam, the BeamStar may work better with one polarization than with the other. It usually works better with the polarization that gives a stronger signal on the BeamStar. Experiment with placing the BA500 at two positions (right angles to each other).

After setting up the camera, all BeamStar features that are described in this manual can be used with the BA500.

22 Specifications

Item	Specification				
Camera	SP620U	SP503U	BeamStar FX 50	BeamStar FX 33	BeamStar FX 33HD
Application	Large beams – high resolution	General purpose, pulsed lasers	General purpose, pulsed lasers	Small beams - low cost	Small beams – high resolution
Spectral Response:	350 - 1320nm 193 – 360nm with UV Image Converter attachment	350 - 1320nm 193 – 360nm with UV Image Converter attachment	350 – 1320nm 193 – 360nm with BeamStar U attachment	350 – 1100nm 193 – 360nm with BeamStar U attachment	350 – 1100nm 193 – 360nm with BeamStar U attachment
Maximum beam size:	7.0 mm W x 5.3mm H.	6.3 mm W x 4.7 mm H	6.3 mm W x 4.7 mm H	4.7 mm W x 3.6 mm H	4.8 mm W x 3.6 mm H
Pixel spacing	4.4µm x 4.4µm	9.9µm x 9.9µm	9.9µm x 9.9µm	7.4µm x 7.4µm	4.65µm x 4.65µm
Number of effective pixels	1600 x 1200 pixels	640 x 480 pixels	640 x 480 pixels	640 x 480 pixels	1024 x 768 pixels
Minimum system dynamic range ¹	62dB (> 1250:1) with no averaging. With averaging 72dB (= 4000:1) or more	64dB (> 1500:1) with no averaging. With averaging 74dB (> 5000:1) or more	60dB = 1000:1 with no averaging. With averaging 70dB=3000:1 or more	60dB = 1000:1 with no averaging. With averaging 70dB=3000:1 or more	60dB = 1000:1 with no averaging. With averaging 70dB=3000:1 or more
Linearity with Power	±1% (from 10% of full scale. ±1.5% from 2% of full scale)	±1%	±1%	±1%	±1%
Accuracy of beam width	±2% for noise levels <1%	±2% for noise levels <1%	±2% for noise levels <1%	±2% for noise levels <1%	±2% for noise levels <1%
Frame rates	Up to 10Hz in 8-bit mode, 8.3Hz in 12-bit mode (slightly less when synchroning with external trigger).	Up to 30 fps (slightly less when synchroning with external trigger).	Up to 30 fps (slightly less when synchroning with external trigger).	Up to 30 fps (slightly less when synchroning with external trigger).	Up to 15Hz (slightly less when synchroning with external trigger).
Shutter duration	From 1/frame rate down to 37.75µs. Manual or automatic control.	From 1/frame rate down to 62.25µs. Manual or automatic control.	From 1/frame rate to 1/8000s. Manual or continuous automatic control.	From 1/frame rate to 1/8000s. Manual or continuous automatic control.	From 1/frame rate to 1/6000s. Manual or continuous automatic control.
Gain control	0dB to 29.4dB in ~840 steps (each step is ~0.035dB). Manual or automatic control	0dB to 32.6dB in ~930 steps (each step is ~0.035dB). Manual or automatic control	0dB to 30dB in ~800 steps (each step is ~0.035dB). Manual or automatic control	0dB to 30dB in ~800 steps (each step is ~0.035dB). Manual or automatic control	0dB to 27dB in ~700 steps (each step is ~0.035dB). Manual or automatic control

¹ Some vendors claim as much as 14 bit dynamic range but this usually refers to the A/D card dynamic range and not the total system dynamic range including the camera which is usually on the order of 55 – 60dB.

Item	Specification				
Trigger	1. BNC connector accepts positive or negative trigger signal from 3 to 24V with pulse width 100ns min. LED on camera indicates triggering. Will synchronize with laser repetition rates up to 1 KHz but will show frames only to maximum frame rate. Exclusive Ophir pre-trigger allows synchronization to even sub-nanosecond pulses without delay between trigger pulse and laser pulse. 2. Same connector can be software configured to provide trigger out to synchron laser. Supports programmable delay on Strobe Out Same connector can accept photodiode trigger (see below)		1. BNC connector accepts positive or negative trigger signal from 3 to 24V with pulse width 1μs min. LED on camera indicates triggering. Will synchronize with laser repetition rates up to 1 KHz but will show frames only to maximum frame rate. Exclusive Ophir pre-trigger allows synchronization to even sub-nanosecond pulses without delay between trigger pulse and laser pulse. 2. Same connector can be software configured to provide trigger out to synchron laser Same connector can accept photodiode trigger (see below)		
Photodiode trigger	Optional photodiode trigger plugs into BNC input on camera, picks up scattered laser light and synchronizes camera automatically with laser. Min peak power necessary is ~300μW/cm² at 500nm. Photodiode unit can clip onto camera or be mounted at a distance on a stand. Photodiode trigger will synch camera regardless of laser pulse duration – even for ns or shorter pulses. Max laser frequency for automatic triggering is 500Hz				
Saturation intensity	~0.7mW/cm² at 633	~0.57mW/cm² at 633	1.3μW/cm².	1.0μW/cm².	0.5μW/cm².
Lowest measurable signal:	0.35nW/cm² at 633nm	0.5nW/cm² at 633nm	0.4nW/cm²	0.6nW/cm²	0.6nW/cm²
Damage threshold	50W/cm² / 1J/cm² with all filters installed.				
Dimensions and CCD recess	96mm X 76mm X 23mm. CCD recess from surface 4.5mm	96mm X 76mm X 16mm. CCD recess from surface 4.5mm	77mm x70mm x 35.7mm. CCD recess from surface 4.5mm	77mm x 70mm x 25.2mm. CCD recess from surface 4.5mm	77mm x 70mm x 25.2mm. CCD recess from surface 4.5mm
Image Quality at 1064nm	Pulsed with trigger synch- excellent Pulsed with video trigger – good CW – good	Pulsed, synched – excellent CW – poor	Pulsed with video trigger – good Pulsed, synched – excellent CW – poor	Pulsed with video trigger – good Pulsed, synched – excellent CW – poor	Pulsed with video trigger – good Pulsed, synched – excellent CW – good
Electrical Characteristics	270mA from 5V bus-powered supply (1.35W)	180mA from 5V bus-powered supply (900mW)	165mA from 12V supply (2W)	165mA from 12V supply (2W)	165mA from 12V supply (2W)
Operation mode:	Interline transfer progressive scan CCD				
Software Supported	LBA-USB, BeamStar		LBA-FW, BeamStar		
PC interface	USB 2.0		IEEE 1394 Firewire		
Minimum host system requirements	Pentium-4 1.7GHz (>2GHz for best performance), 256 MB Memory. Operating system, Windows XP or Vista (32 bit). USB 2.0 Port		Pentium-4 1.7GHz (>2GHz for best performance), 256 MB Memory, IEEE 1394 Interface Requires PCI or CardBus Slot. Operating system, Windows XP or Vista (32 bit)		

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